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F-15 8.33-PERCENT MODEL INTERNOZZLE DYNAMIC PRESSURE ENVIRONMENT

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NOTICE

This technical report has been reviewed and is approved for publication.

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14. ABSTRACT ***(Maximum 200 Words)***
The F-15 Strategic Programs Office (ASD/TAF) requested the Structural Vibration and Acoustics Branch to record and analyze data from a wind tunnel test on an 8.33-percent model F-15 aircraft. The objective was to assess the effect various model configurations had on the aeroacoustic loads around the aft nozzle region.

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FOREWORD

This effort was performed by the Structural Vibration and Acoustics Branch (FIBG), Structures and Dynamics Division, Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. It was an acoustic test support effort for the F-15 SPO (ASD/TAF). The project engineer from TAF was Mr Rick Johns n. FIBG was responsible for recording, reducing and analyzing the data. The tests were performed in the AEDC PWT-16T wind tunnel facility.

This reports presents the acoustic data from all of the test conditions and microphones on the model. Appreciation is given to Messers Mike Banford, Ed Huffman, and Chuck Willhite who were the electronic technicians during the program.

This technical memorandum has been reviewed and is approved.

DAVEY L. SMITH, Chief
Vibration & Acoustics Branch
Structures & Dynamics Division

I. INTRODUCTION

The F-15 Strategic Programs Office (ASD/TAF) requested the Structural Vibration and Acoustics Branch to record and analyze data from a wind tunnel test on an 8.33 percent model F-15 aircraft. The objective was to assess the effect various model configurations had on the aeroacoustic loads around the aft nozzle region.

This report presents the results obtained from the wind tunnel test. The model was provided by the McDonnell Douglas Aircraft Company (McAir). Three approaches were investigated: vented vertical tails with rudder deflections, B-1 type vanes and boom configuration, and F-18 type centerbody. The acoustic environment associated with each approach was measured and analyzed, and the best features of each were applied to the next set of tests.

Jet fighters and bombers have less drag penalty and can achieve better performance when external flaps are attached to the engine exhaust nozzles. Previously, aeroacoustic loads resulted in structural problems on twin jet nozzle configuration aircraft. Currently, F-15 aircraft fly without these flaps. It is hoped that an improved design of the vertical tails and center body fairings will reduce the aeroacoustic loads on the flaps and enable them to be reinstalled.

The unsteady pressure oscillations can be explained by a feedback mechanism which amplifies the instability modes of a free jet. When two jets are closely spaced they can couple together enhancing the feedback

resulting in significant amplification of the instability modes and hence the aeroacoustic loads.

Aeroacoustic data were obtained from six of the nine pressure transducers that were installed around the right hand nozzle. These data were reduced to power spectral densities from 0 to 5000 Hz. The tests were performed at the AEDC 16T transonic wind tunnel facility, capable of continuous-flow, closed-circuit operation within a Mach number range of 0.20 to 1.60. A similar test was recently performed on a 4.7 percent model of the F-15 aircraft. The results of that test are presented in Reference 1. A comparison is made between the current results and those.

II. DESCRIPTION OF TEST MODEL

The test article was an 8.33 percent scale model of an F-15 aircraft. The model changes investigated were venting at the base of the vertical tail, rudder and base tab deflections, recontoured boom fairing, flow vanes, and nozzle centerbody. These configuration variables are illustrated in the drawings of Figures 1, 2, and 3. The specific configuration numbers and descriptions are given in Table I. Figures 4 through 15 are photographs of each of the 12 configurations.

III. DESCRIPTION OF INSTRUMENTATION AND DATA ACQUISITION

Nine Kulite Pressure Transducers (model LQ-125-10) were used to measure the dynamic pressure environment on the nozzle of an 8.33 percent scale model of an F-15. They were installed on the right hand nozzle at locations shown in Figure 16. The signals from the Kulites were first amplified 10 dB (20 db??) through a 12 channel/AYDIN-VECTOR PDCS-100 signal conditioning box, which also provided the constant current source (CCS) to power the Kulite transducers. This box was located in the tunnel plenum, as shown in Figure 17, to keep electronic noise down and the supply current level to a minimum.

The Structural Vibration and Acoustics Branch's Data Acquisition and Analysis Van (Van-1) was parked outside the 16T high bay, next to the control room. Power cables and 250 foot signal wires were located in the plenum area of the wind tunnel, below the test section. The constant current power supplies were situated there. From the CCS the connecting cables were strung to the model through the sting.

The signal from the PDCS-100 traveled through 250 feet of three-lead, shielded cable to FIBG's Van-1 to another amplifier stage. The signals were then recorded on magnetic tape using a Honeywell Model 96 FM tape recorder. Recorded data was played back from the 96 recorder into an ONO SOKKI CG-910 duel channel FFT analyzer. The analyzer sent the processed data to a Hewlett-Packard 7470A digital plotter. Plots were made of the data from 0 to 5000 HZ in the form of Power Spectral Density (PSD, psi^2/Hz).

SPL ?? → No sign of on the plots.

IV. TEST PROCEDURE

The model was positioned in the tunnel for the first test configuration. An end-to-end calibration was made on each Kulite and recorded on magnetic tape. The tunnel was brought up to the test level and allowed to stabilize.

FIBG personnel in Van-1 recorded 30 seconds of Kulite data when the tunnel was on condition. During each model change, prior data points were analyzed with the FFT analyzer. Plots were made of 2 channels at a time, which were selected by McAir personnel and FIBG's engineers. A post-test calibration was conducted and recorded on tape.

V. DISCUSSION OF RESULTS

Acoustic data were obtained for all twelve configurations. Details of each of the model configurations are listed in Table I. The data from each of the microphones were reduced into Power Spectral Densities (PSD, psi^2/Hz). Configuration 14 (Basic F-15E aircraft with no vanes or rudder deflection) was the baseline configuration and the noise levels measured for each of the other configurations were compared to it.

CONFIGURATION EFFECTS

Figures 18 through 29 show the comparisons between the baseline and each configuration for spectra from Kulite 8 for a Mach number of 0.9 and NPR of 4.8. Reviewing all of the figures reveals that there are no significant effects, suppression or amplification, for any of the configurations at this location on the nozzle.

NPR EFFECTS

Figures 29 and 30 present spectra from microphone 8 for nozzle pressure ratios of 1.5, 2.7, 3.3, 4.8, and 5.6 for a wind tunnel Mach number of 0.9. It is very evident that NPR did not affect the acoustic levels at this location. It was observed at all other locations and for all configurations tested that NPR did not affect the acoustic levels. To observe the effect of the nozzle flow alone, the tunnel was left off and the NPR was varied from 1 to 6.0. The measured acoustic levels for NPRs less than 3.3 were so low that they were below the dynamic range of

the instrumentation and thus invalid. The spectra for NPRs of 3.3 up to 6.0 are shown in Figure 31. The levels are considered low in regards to acoustic fatigue of structure, but more interesting are the narrowband tones. These are supersonic jet screech tones. They are present in the spectra when the tunnel was off but when the tunnel is flowing, simulating forward flight, the jet screech tones are not clearly visible (Figures 18-29). If they are still generated, they are below the broadband levels associated with the tunnel flow.

ANGLE OF ATTACK EFFECTS

Acoustic data were obtained for angles of attack of -4, 0, 4, and 10 degrees. Spectra for all four angles are shown in Figure 32. The angle of attack has a larger effect on the levels than either configuration or NPR. In general, the levels decrease with increasing angle of attack. Since the levels are significantly affected by the angle of attack, it appears that the aircraft boundary layer is the primary source of noise, or the jet noise generation is being affected by the change in flow.

CIRCUMFERENTIAL VARIATION

Spectra from various circumferential locations (Fig 16) on the nozzle for configuration 14 are shown in Figures 33 and 34. Microphone 8 was in the internozzle region and resulted in the highest measured levels at most frequencies. However, near the twin jet coupling frequency (approximately 700 Hz, found by scaling from flight data) microphone 6 displayed the highest level. The distribution of the levels on a B-1

wind tunnel model presented in Reference 1 also show the maximum level occurring near this internozzle location. The B-1 level distribution from Reference 2 is shown in Figure 35. All of the configurations tested in the current program displayed essentially the same trends.

COMPARISON TO OTHER DATA

A 4.7 percent model of the F-15 aircraft was tested at NASA Langley Research Center. The results are presented in Reference 1. Acoustic data were obtained on the nozzle under similar test conditions as the current test. Data from similar positions on the nozzle from both 8.33 and 4.7 percent model wind tunnel tests are compared in Figure 36. The data from the 8.33 percent are from Kulite number 8. They both are for a wind tunnel Mach number of 0.9 and NPR of 3.5. The data agree fairly well at the lower frequencies but the smaller model resulted in higher levels at the higher frequencies. This would be expected since the boundary layer is thinner on the smaller model and broadband acoustic energy tends to scale with thickness. Also, the peak at the lower frequencies shifts to a lower frequency for the current model as expected (see Reference 1).

The flight data shown in Figure 36 are for a Mach number of 1.03 while operating at military power. The level was measured in the internozzle region. The flight data are 30 dB higher than the wind tunnel results. The reason for the large spread is partially understood and is discussed in detail in Reference 3. Basically, different jet instability modes are excited in the wind tunnel then those in flight.

Some modes permit the jets to couple and thus result in much higher acoustic environment while others do not result in jet coupling. Even ground runup of the F-15 aircraft does not result in high acoustic levels in the internozzle region (Reference 4).

With the current level of understanding it appears difficult to simulate the full scale flight environment in a ground test facility. Since both forward speed and jet temperature affect (Reference 3) the instability of the jet, they must be considered in future tests. Further basic research is needed to improve our understanding of the problem.

VI. SUMMARY AND CONCLUSIONS

A wind tunnel test was performed to study drag reduction techniques for the F-15 aircraft and their impact on the acoustic environment on the aft nozzles. None of the configurations tested had significant impact on the internozzle acoustic environment. This is largely due to the lower levels measured in the internozzle region. It is believed that the necessary instability modes of the jets were not excited, keeping the jets from coupling and generating high acoustic levels. If the same configurations were tested in flight, where much higher acoustic levels do occur, they may have significant impact on the levels.

The measured levels agree well with previous data from a 4.7 percent F-15 wind tunnel test but are approximately 30 dB below flight data. Since representative flight acoustic levels were not measured on the baseline configuration, an assessment of the effectiveness of the configuration changes to reduce the levels cannot be made. Until the twin-jet acoustic phenomenon is better understood so that a ground test can be performed which results in representative flight levels, full scale flight testing is recommended.

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2. Berndt, D.F., "Dynamic Pressure Fluctuation in the Internozzle Region of a Twin-Jet Nozzle," SAE 841540, October 1984.

3. Seiner, J.M., and Manning, C.M., "Dynamic Pressue Loads Associated with Twin Supersonic Plume Resonance," AIAA-86-1539, 1986.

4. Conversation with J.M. Seiner of NASA Langley Research Center.

TABLE I

CONFIGURATION DEFINITION

CONFIGURATION	CENTERBODY	TAILBOOM	TAIL	VANE	RUDDER
14	F-15E	F-15E	Basic F-15	Off	0
15	Truncated Tail Hook Exposed	"	"	"	"
16	F-15E	"	Raised	"	"
17	"	"	Vented	"	"
18	"	"	Basic F-15	"	Tab 10 INBD
19	"	"	"	"	Tab & Rudder 10 INBD
20	"	"	"	B-1 Type	0
21	"	INBD Fairing Off	"	Off	"
22	"	Recontoured	"	"	"
23	F-18 Type	F-15E	"	"	"
24	F-15E	"	"	"	Rudder 10 INBD
25	"	"	Off	"	

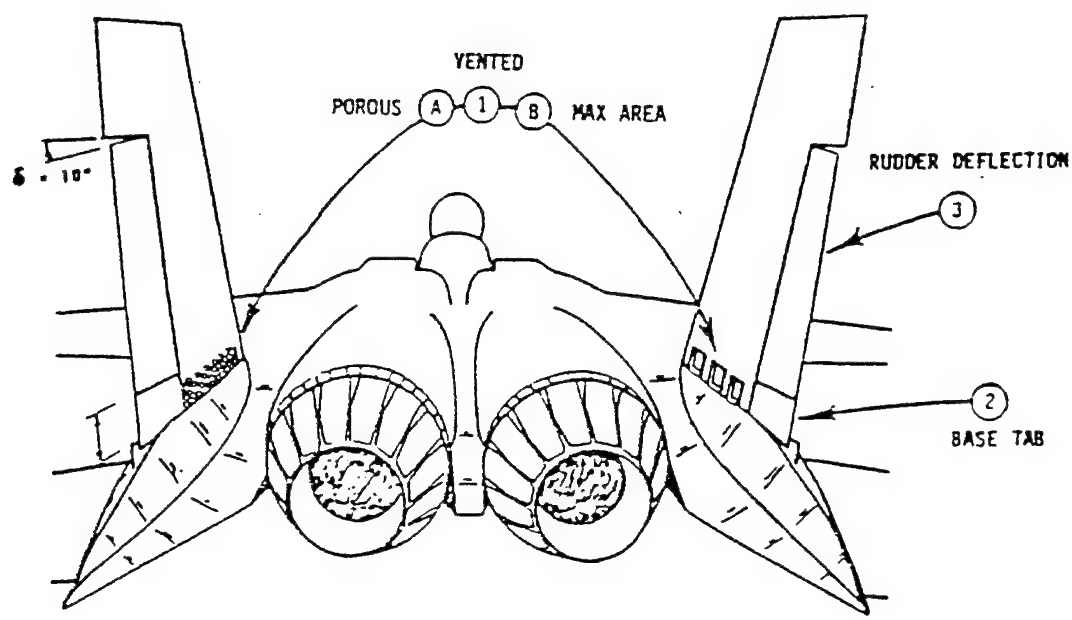


Figure 1 Configuration Variables Venting, Rudder Deflection, and Base Tab Deflection

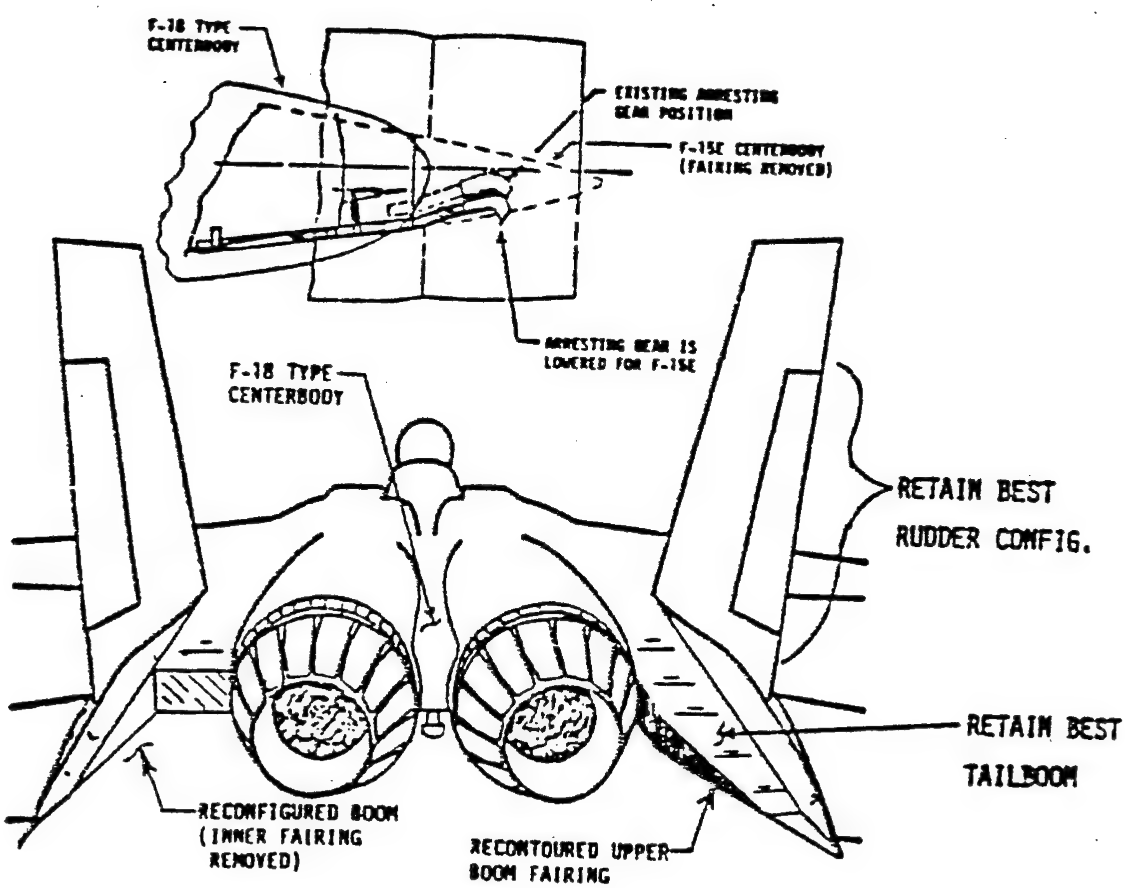


Figure 2 Configuration Variable F-18 Type Centerbody

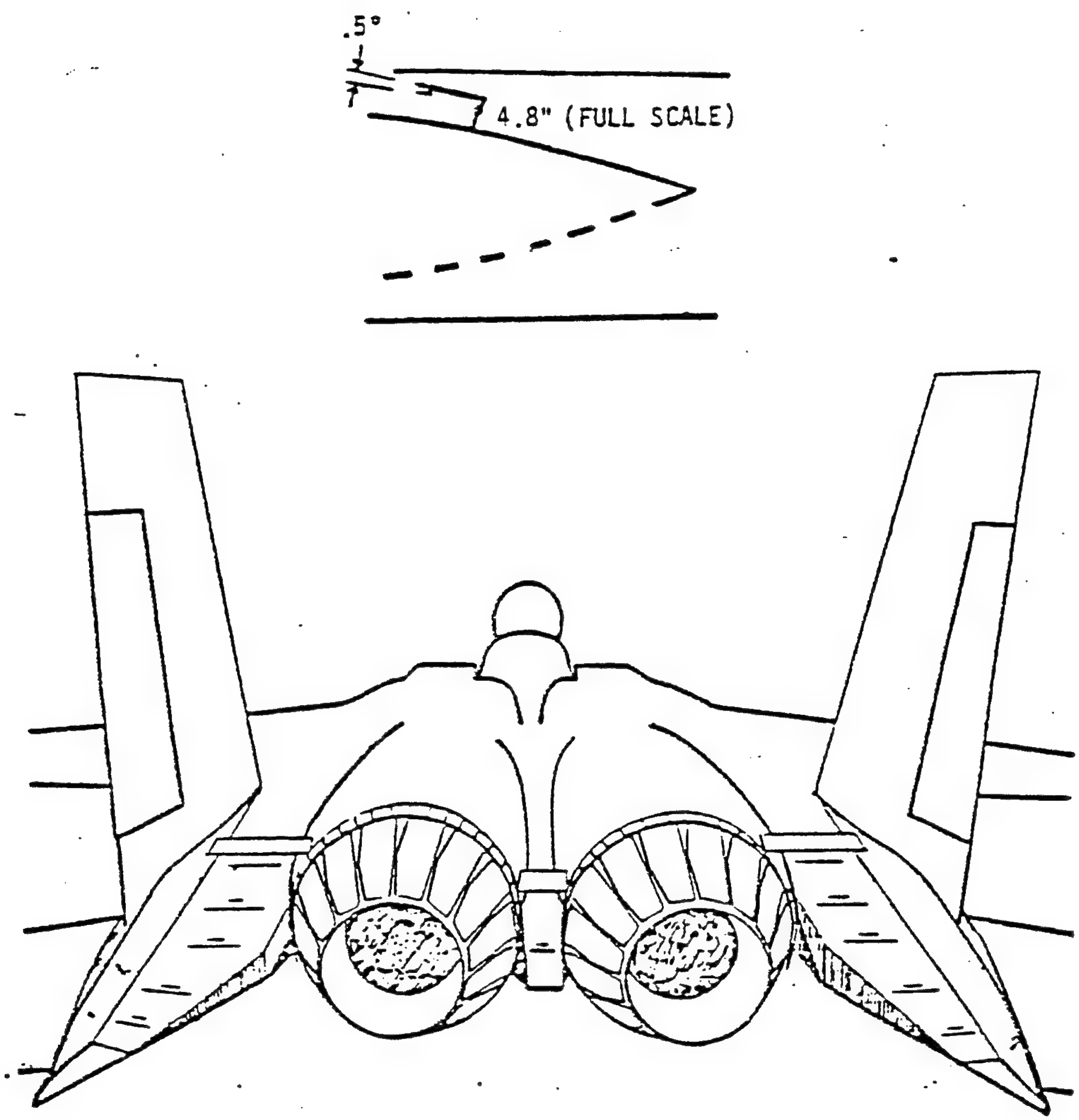


Figure 3 Configuration Variable Centerbody/
Boom Vane Concept

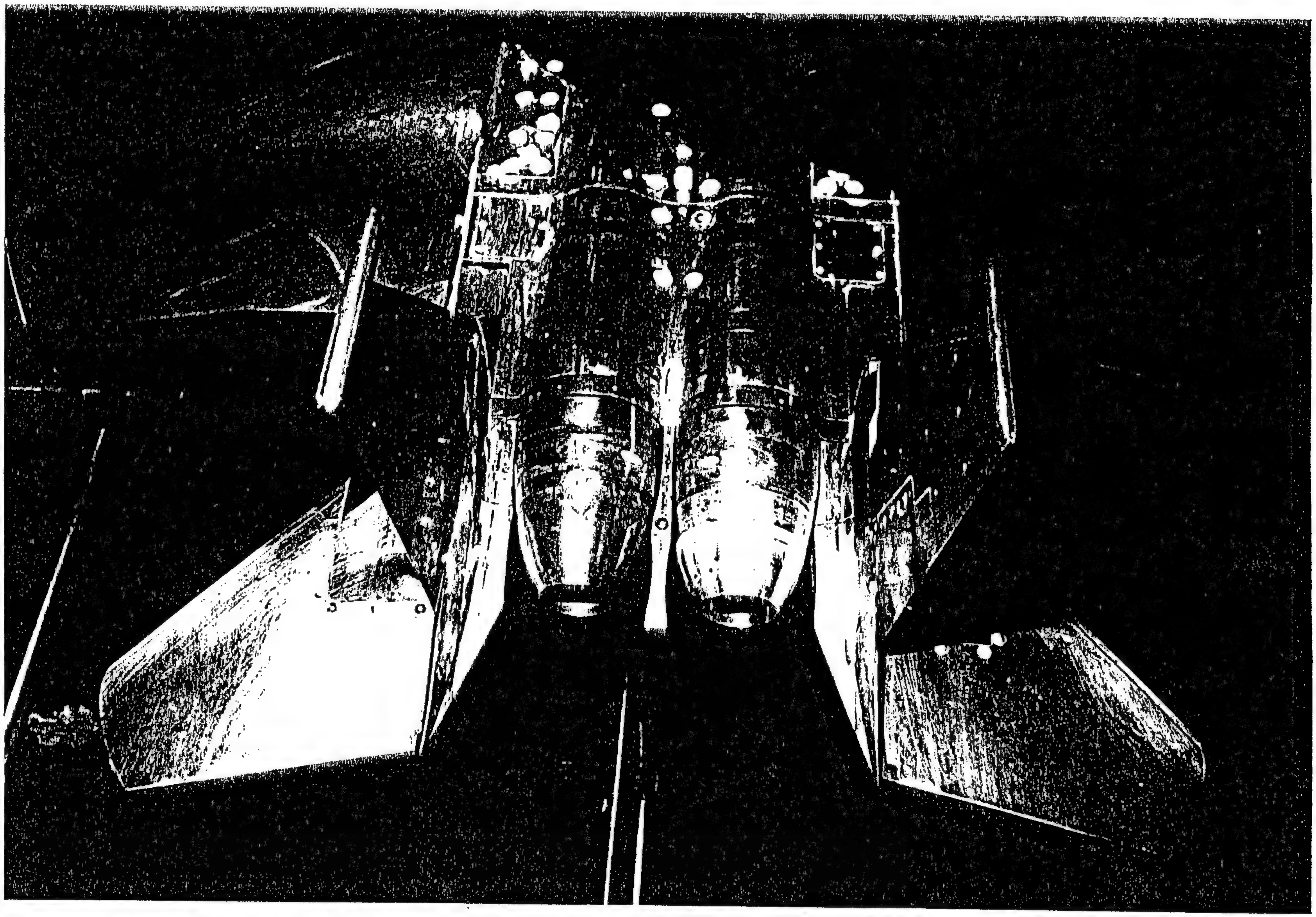


Figure 4 Photograph of Configuration 14

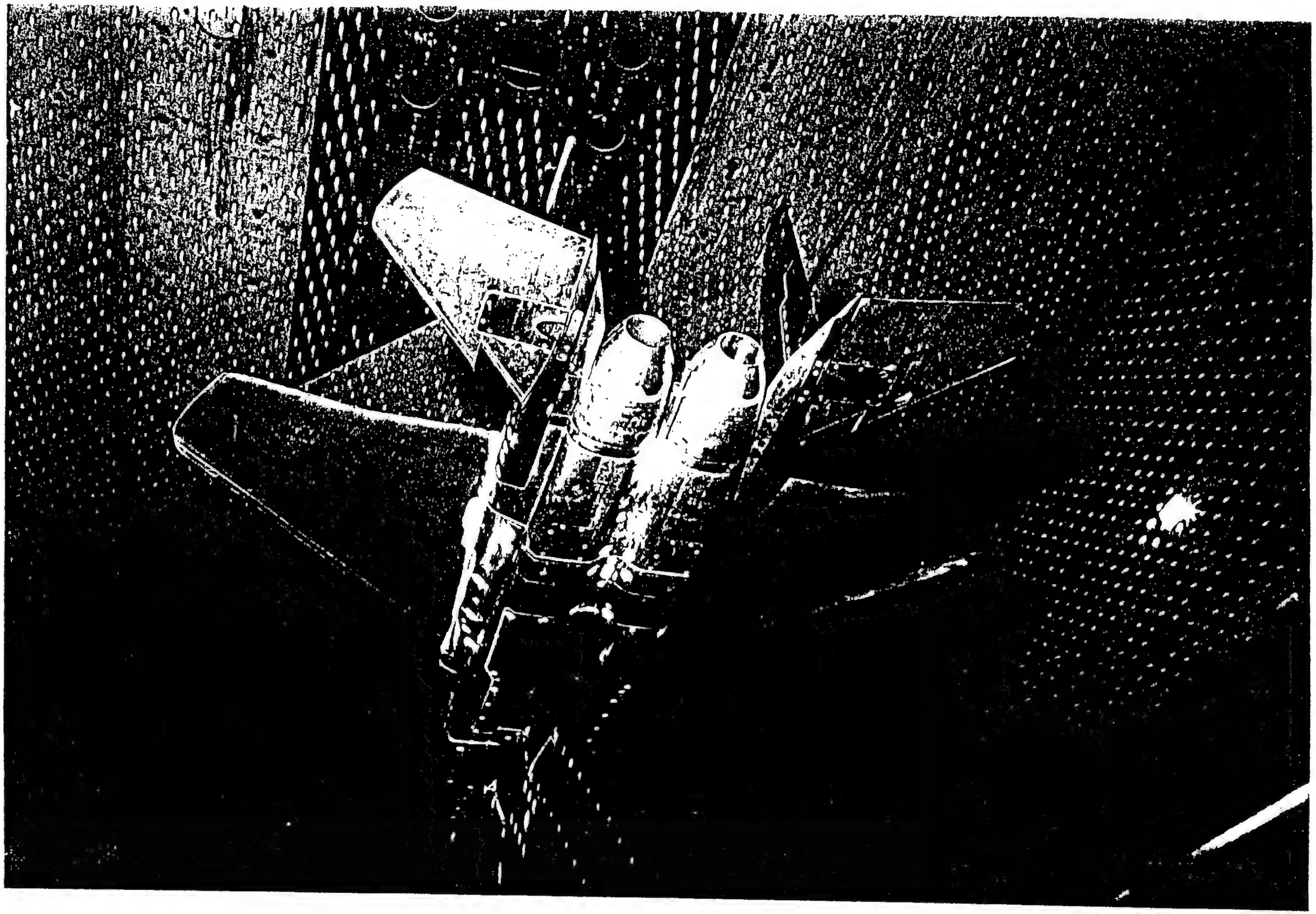


Figure 5 Photograph of Configuration 15

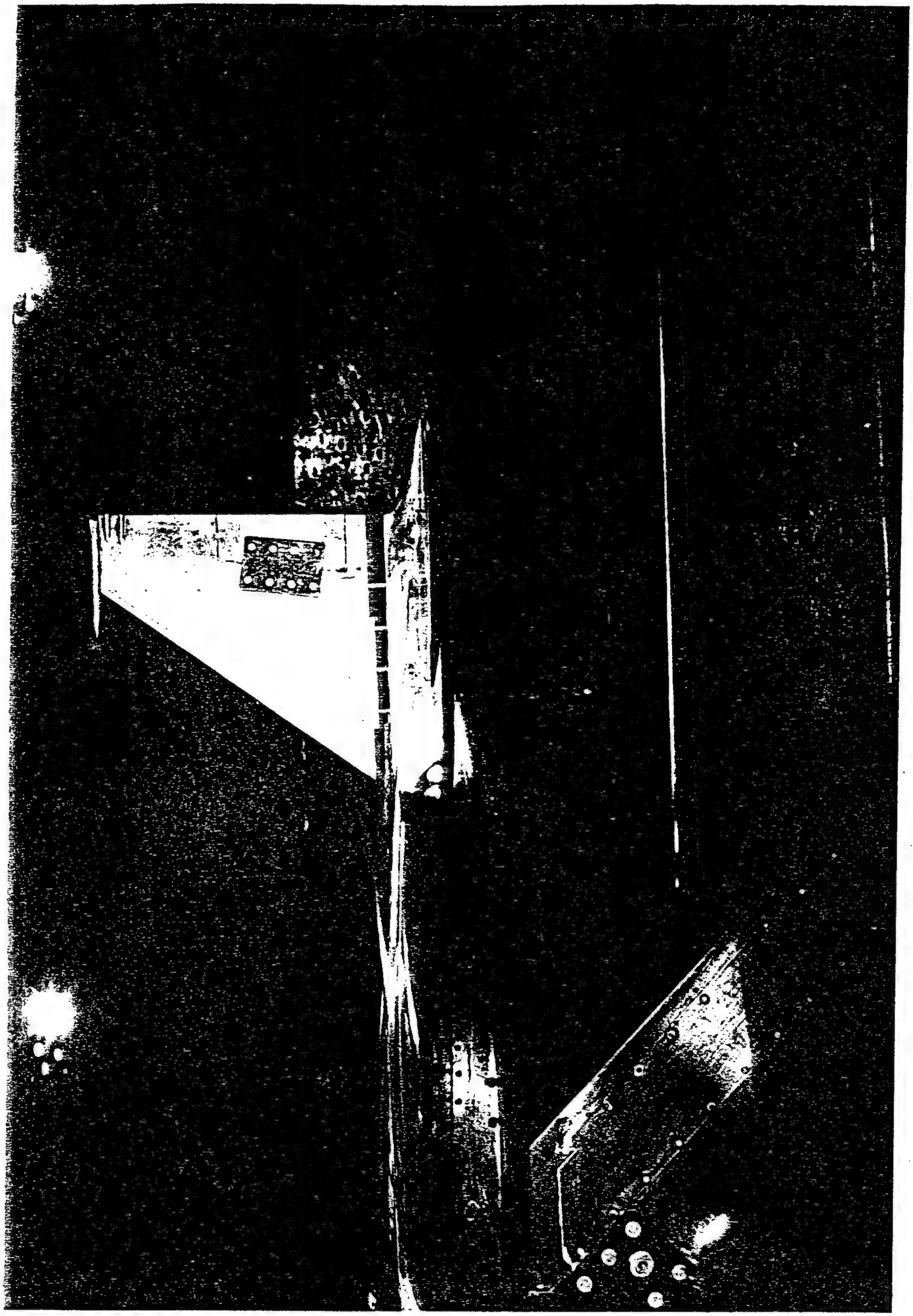


Figure 6 Photograph of Configuration 16

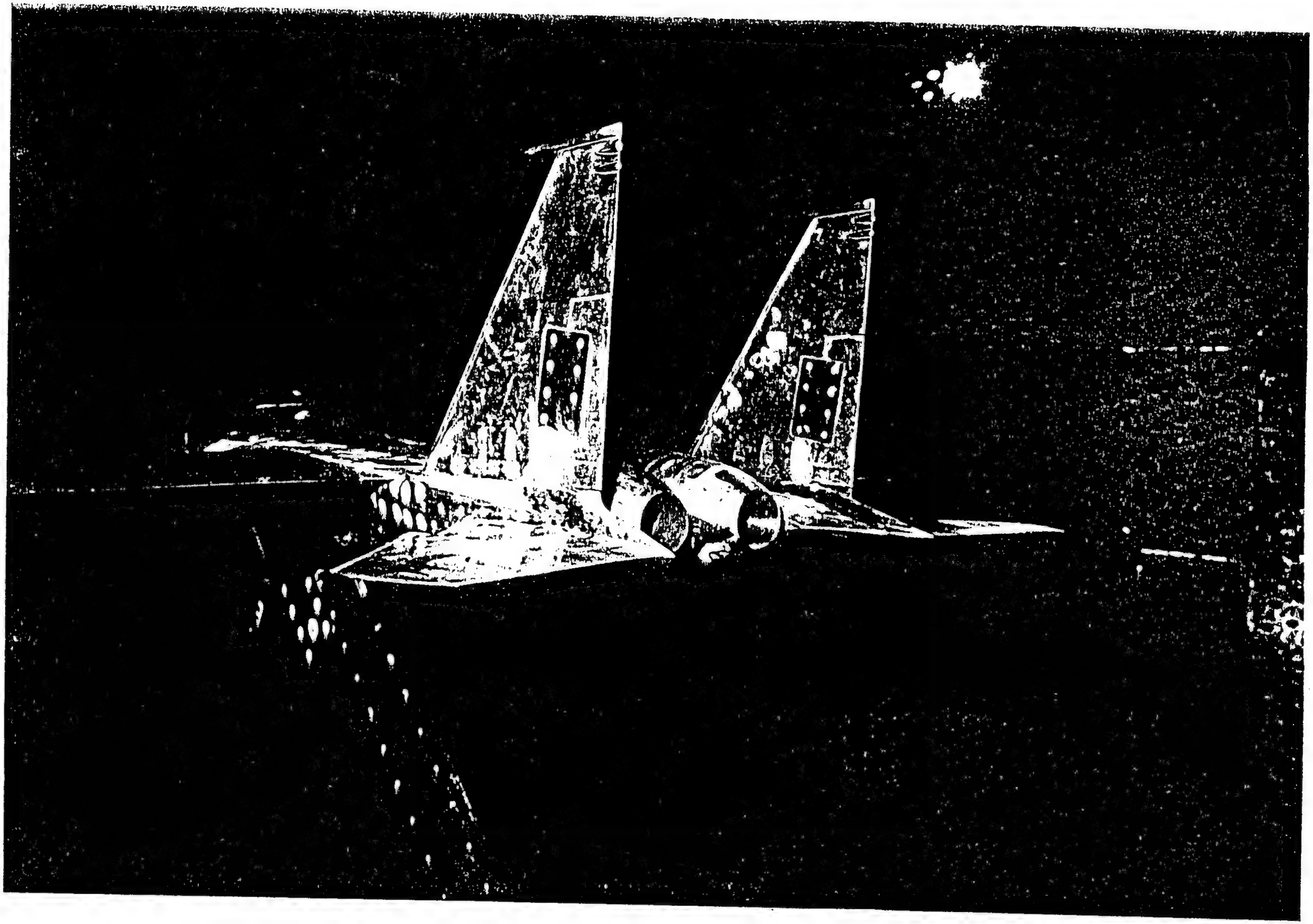


Figure 7 Photograph of Configuration 17

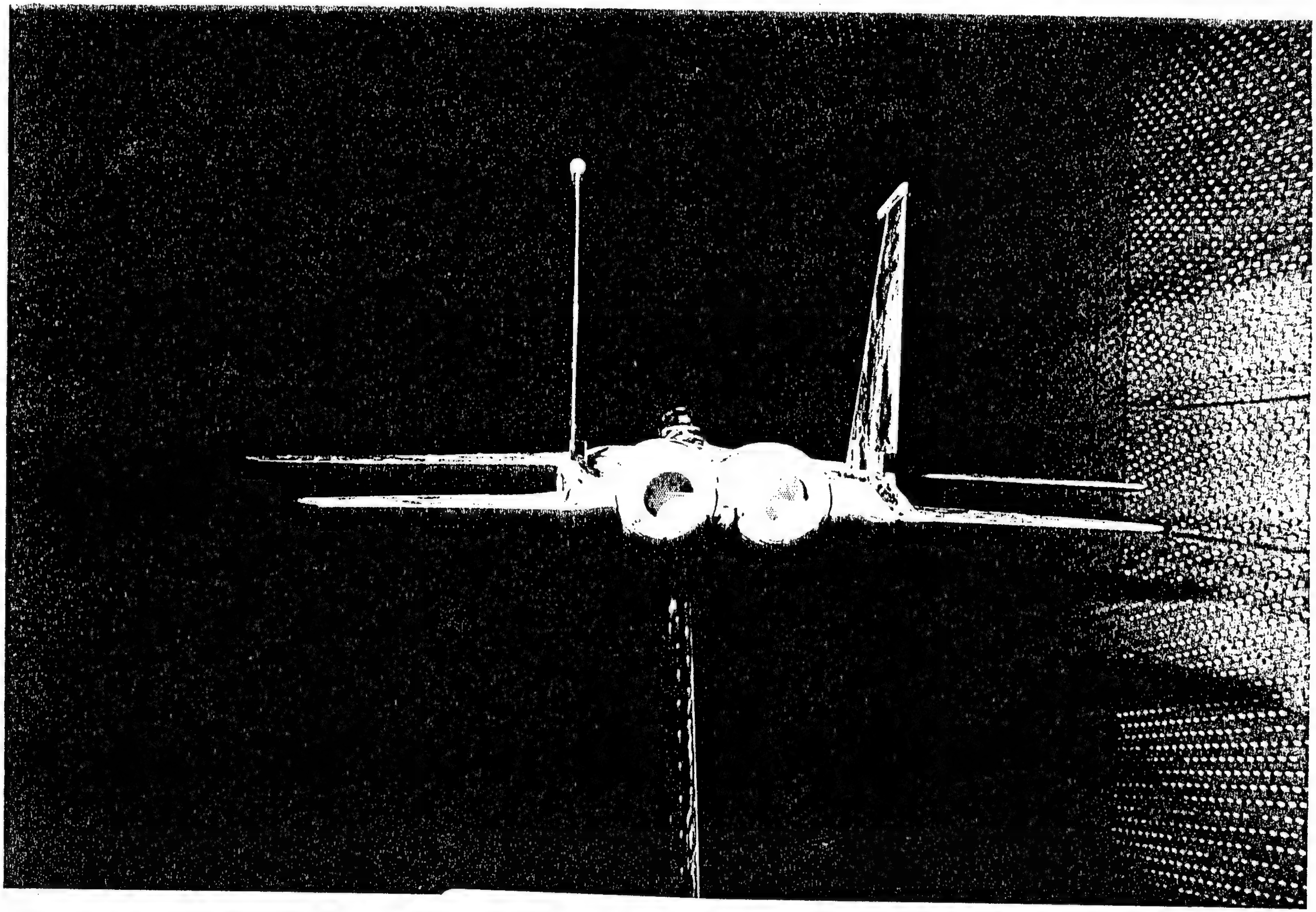


Figure 8 Photograph of Configuration 18

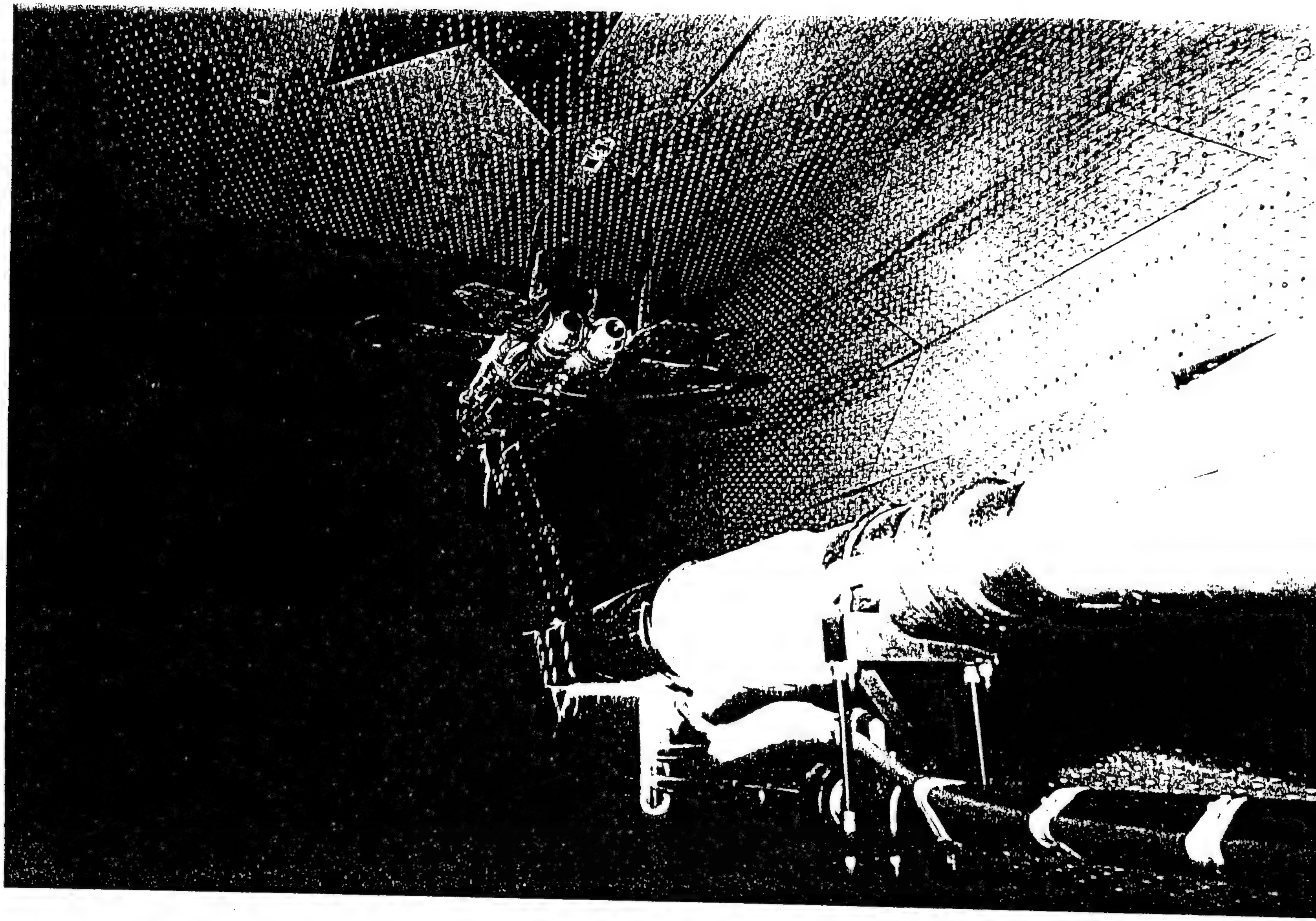


Figure 9 Photograph of Configuration 19

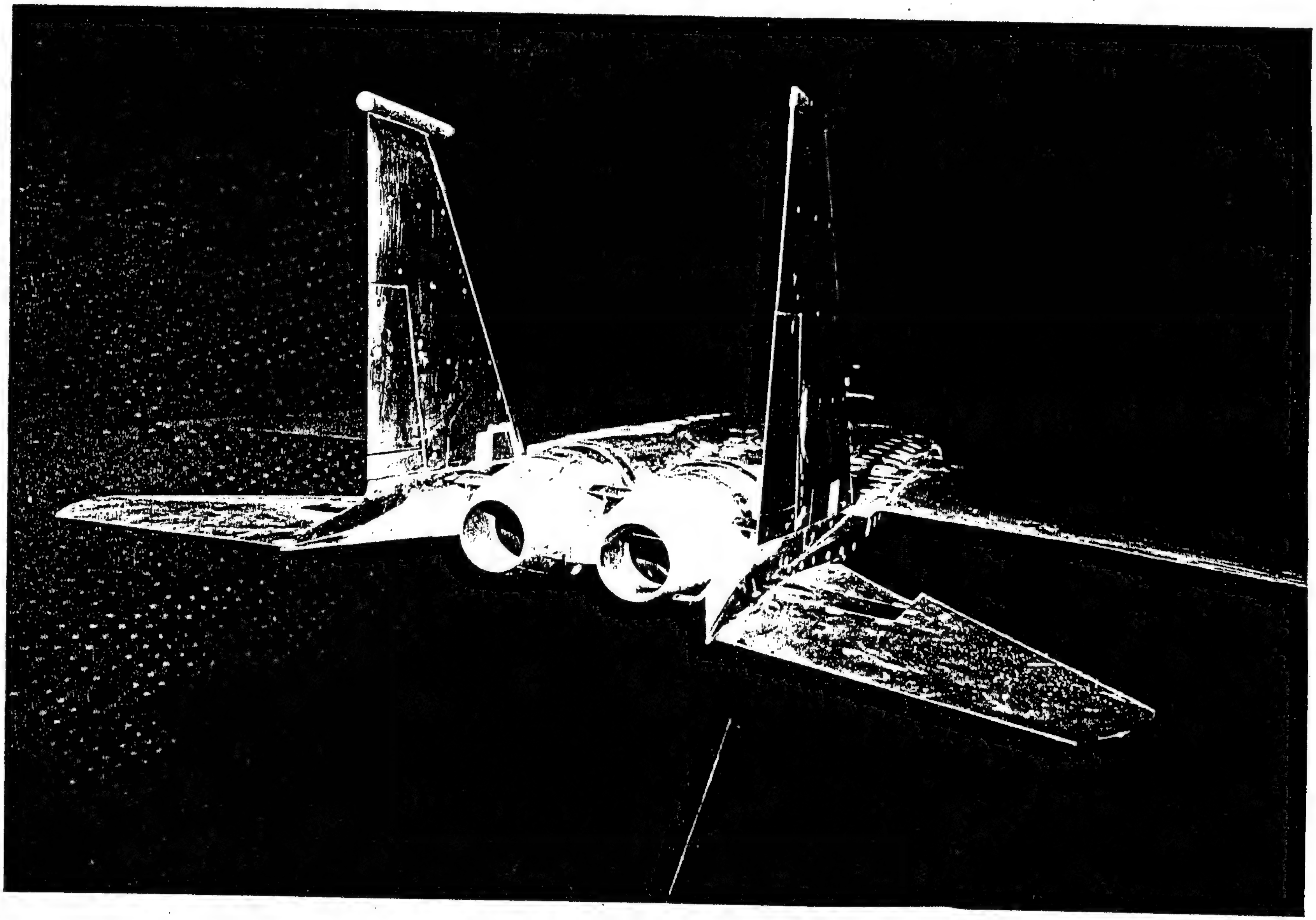


Figure 10 Photograph of Configuration 20

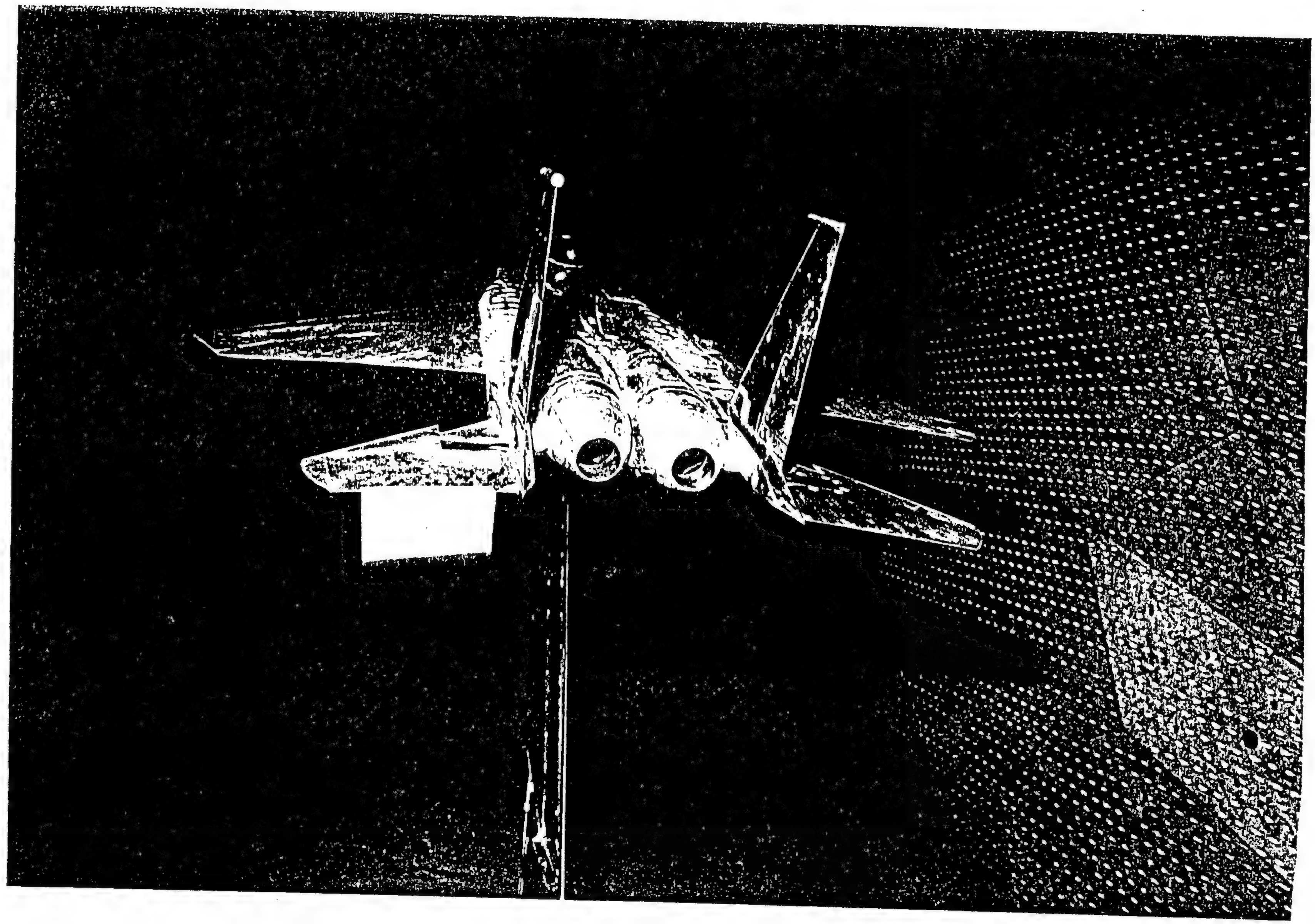
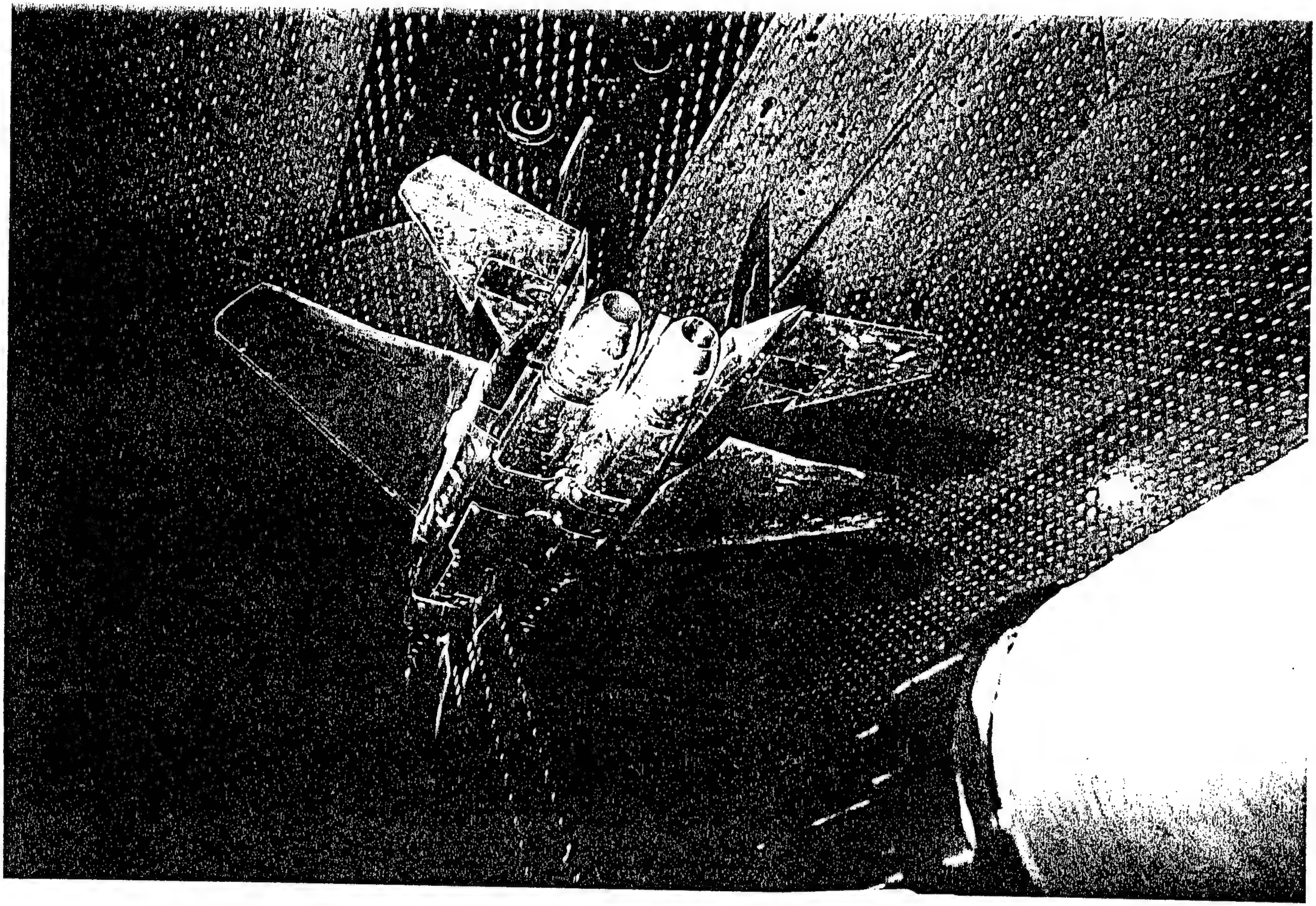


Figure 11 Photograph of Configuration 21



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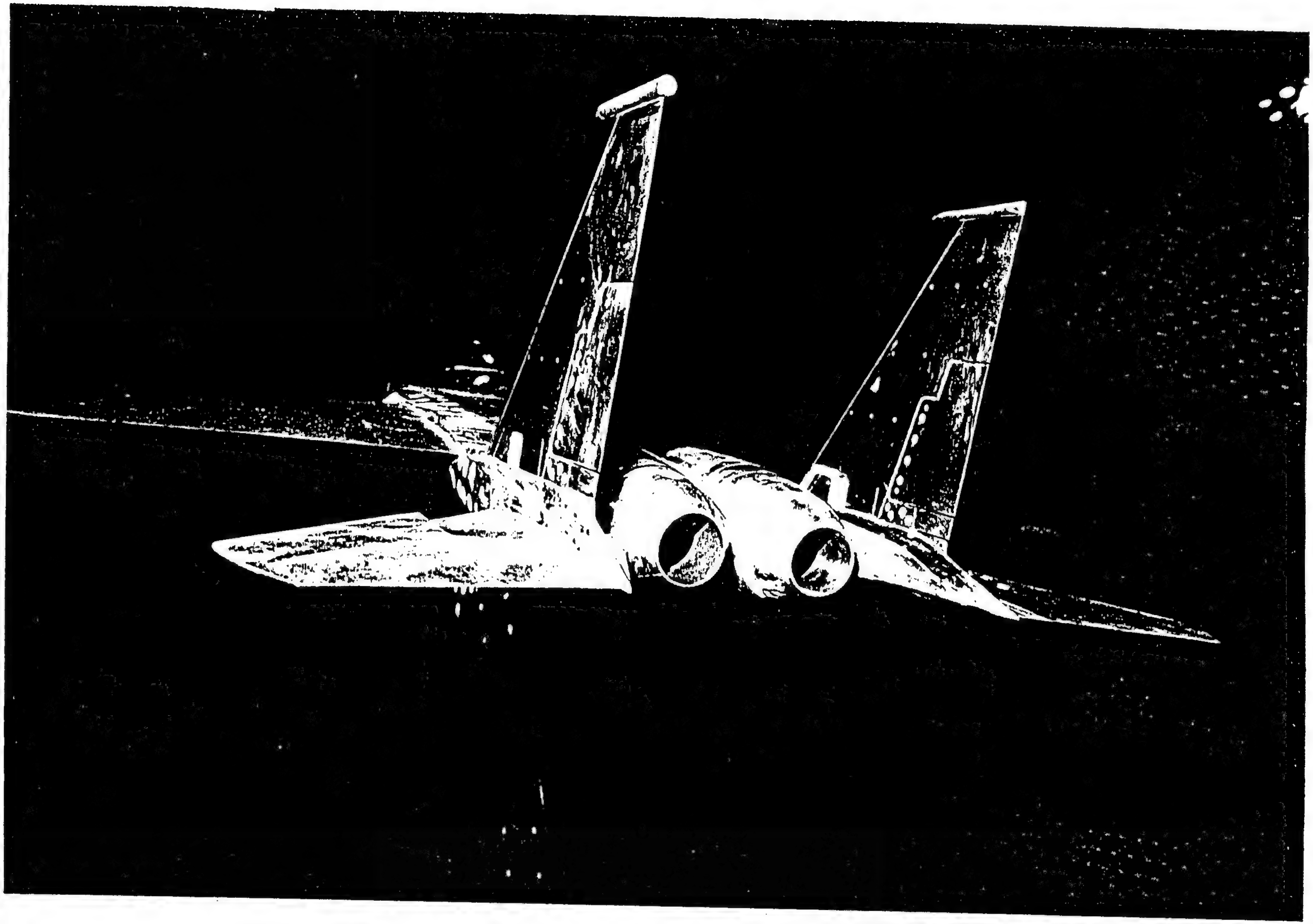

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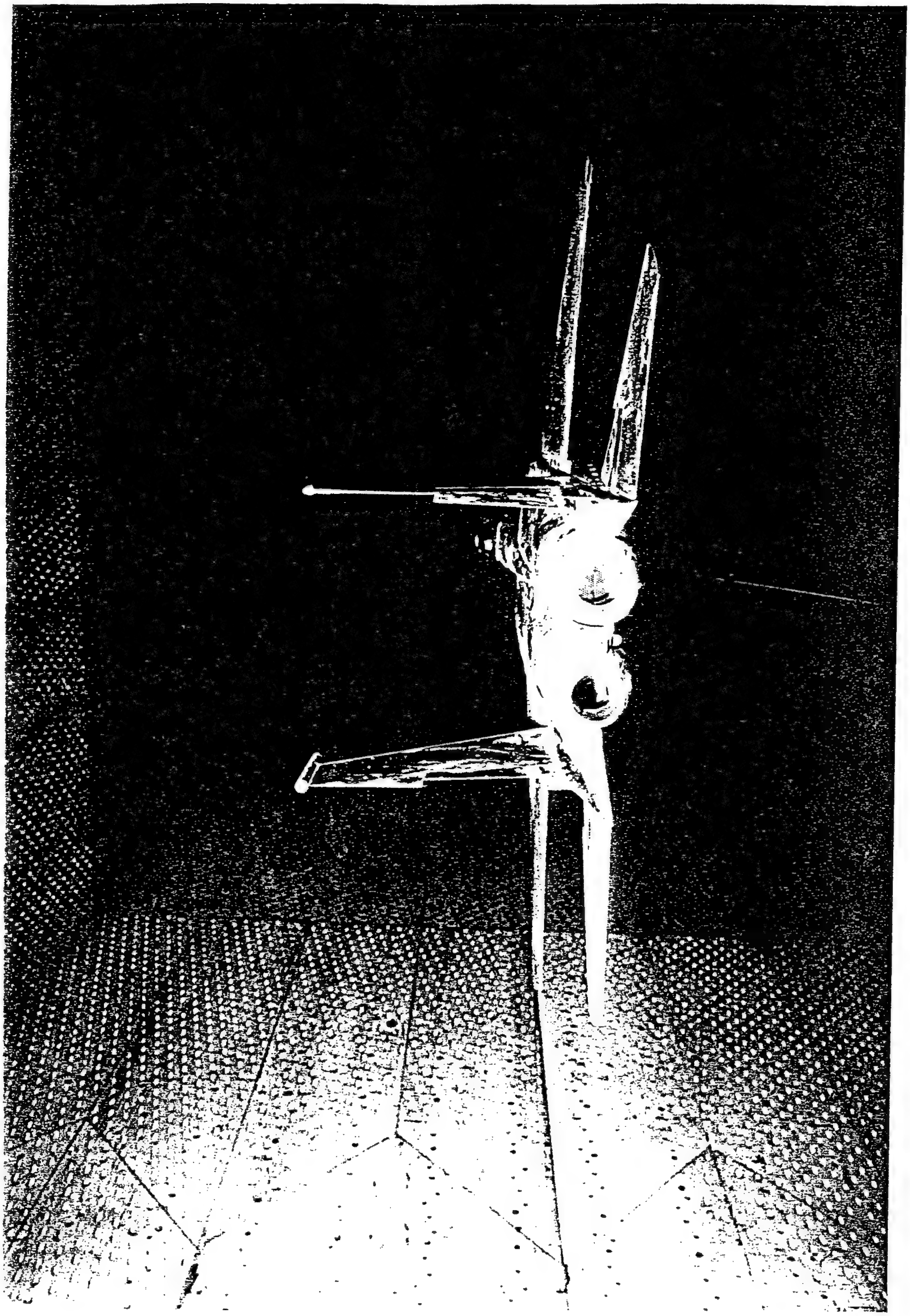

Figure 14 Photograph of Configuration 24

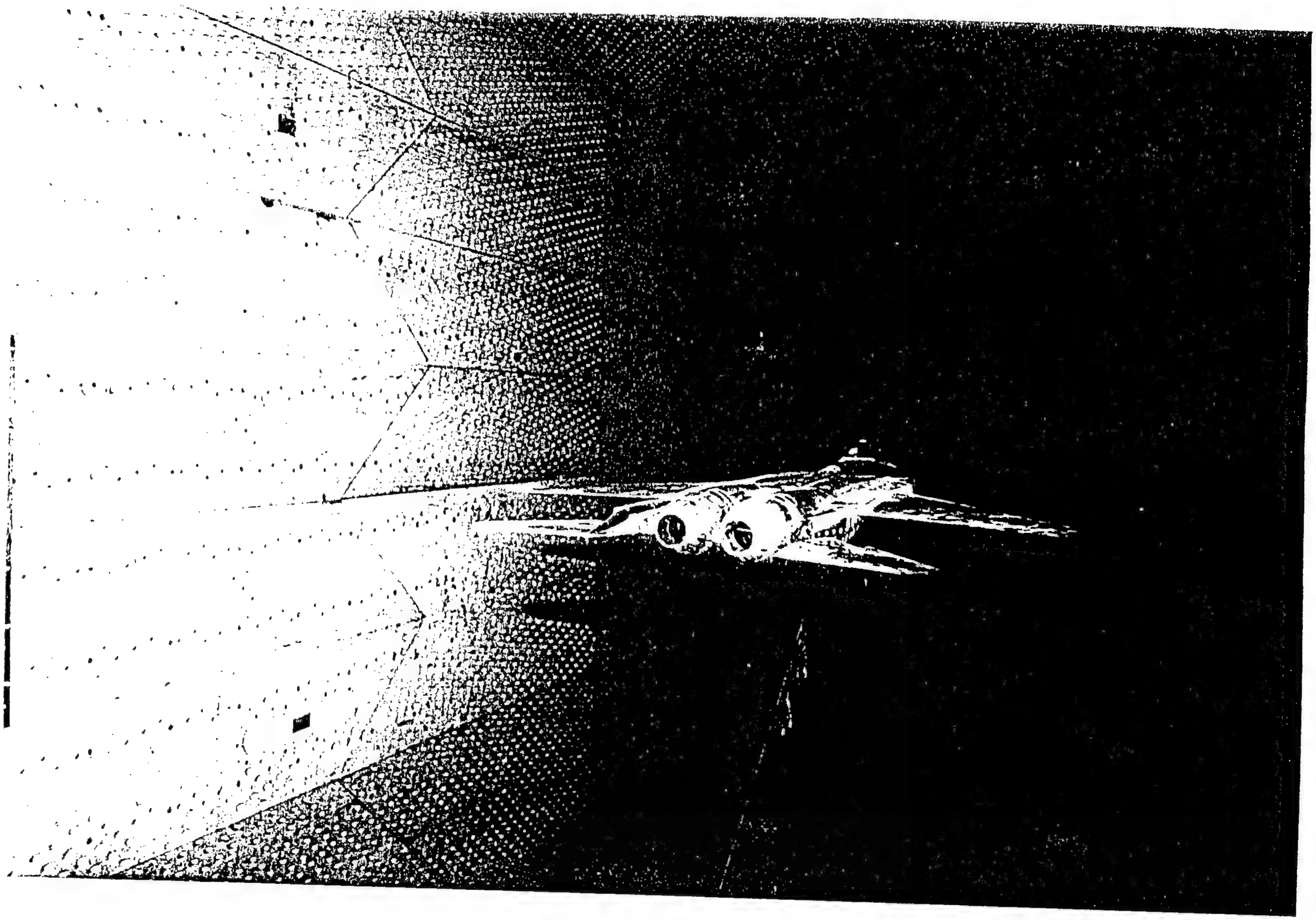

Figure 15 Photograph of Configuration 25

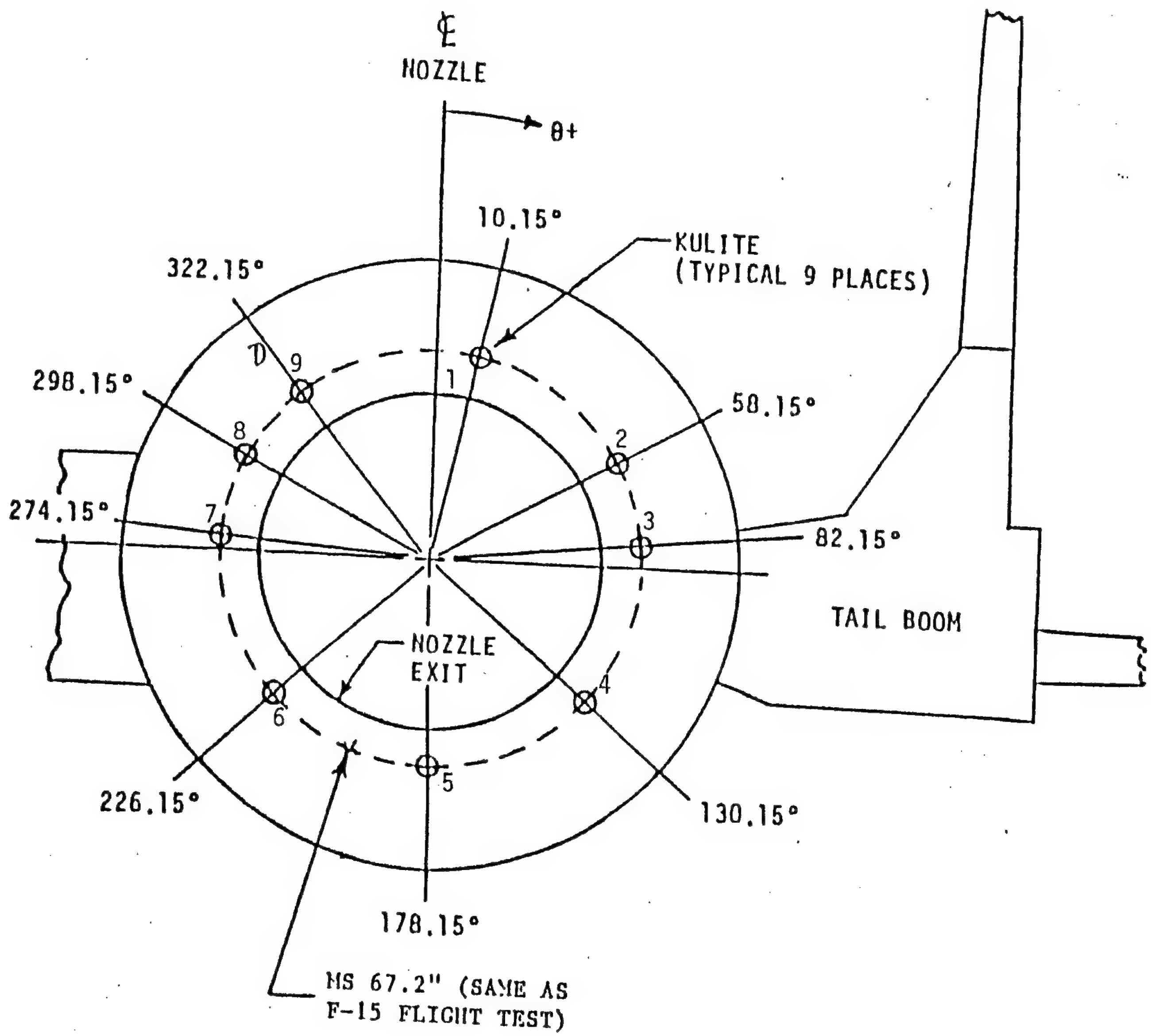

Figure 16– Kulite Installation on

R/H GE Dry Power Nozzle

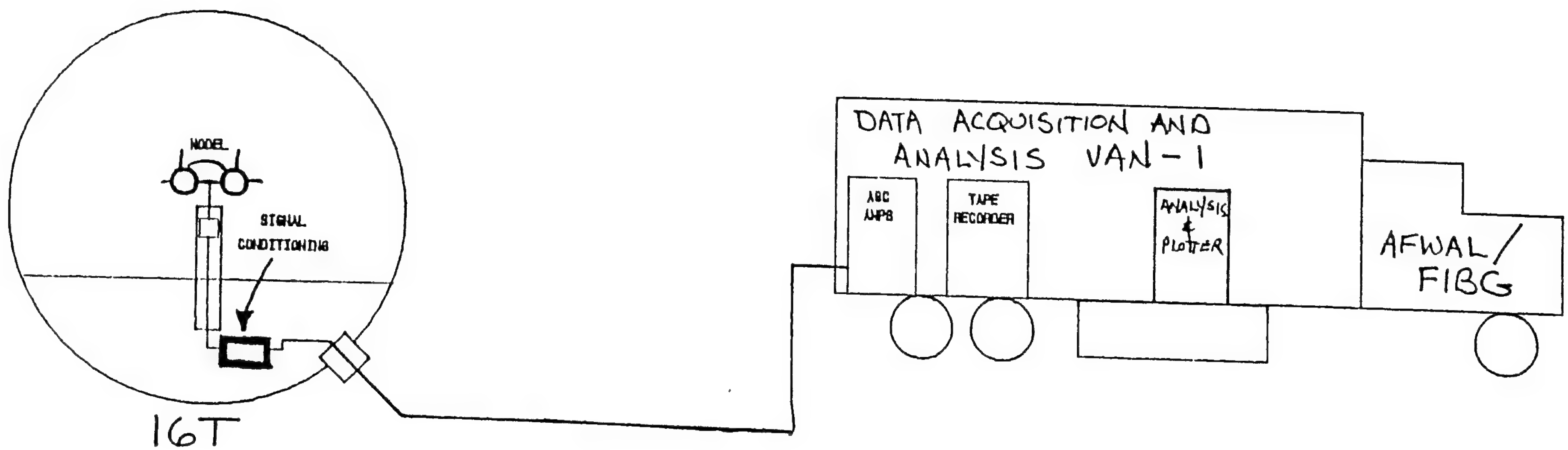

Figure 17 Location of Van & Signal Conditioning Equipment

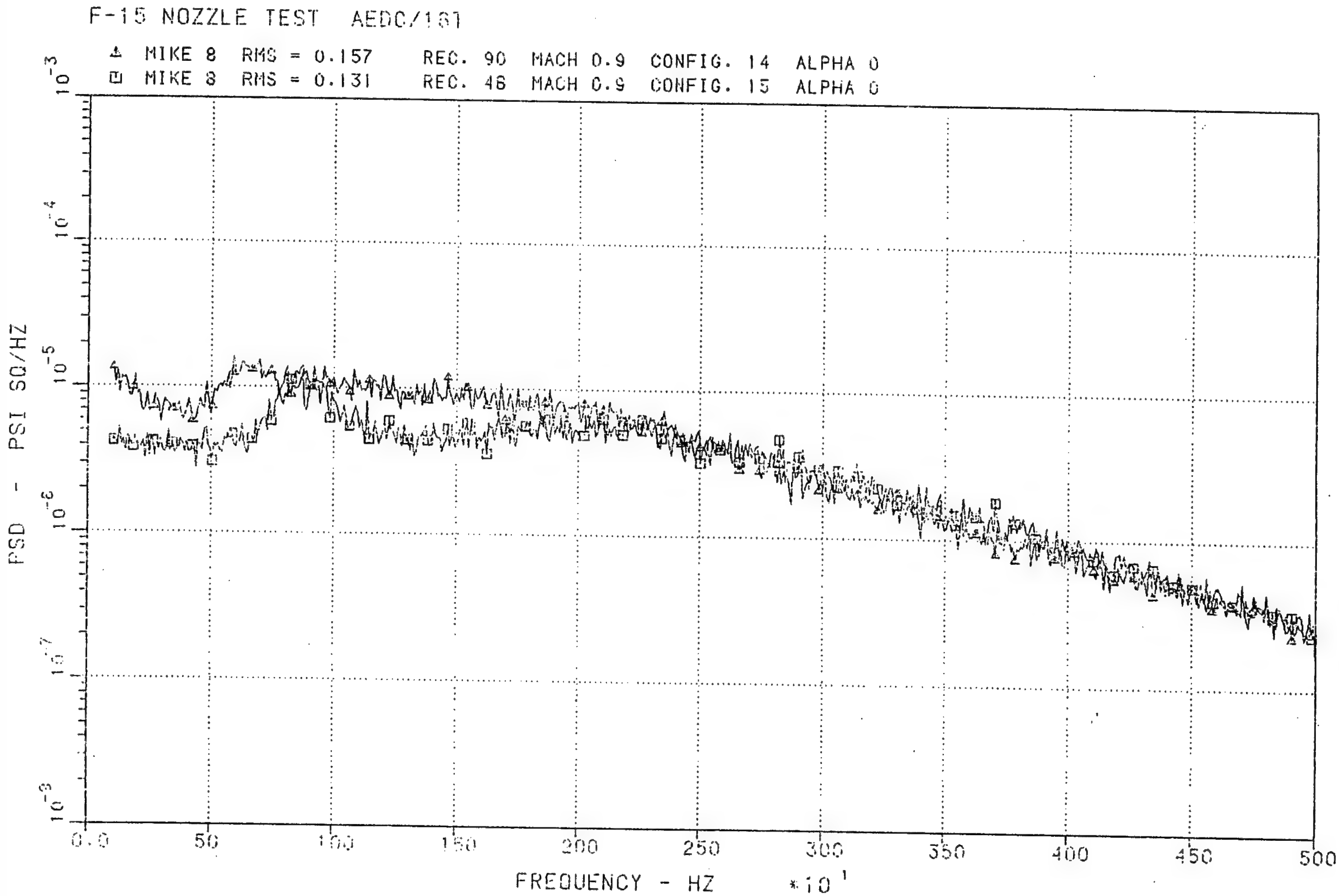

Figure 18 Power Spectral Densities For Configuration 14 and 15

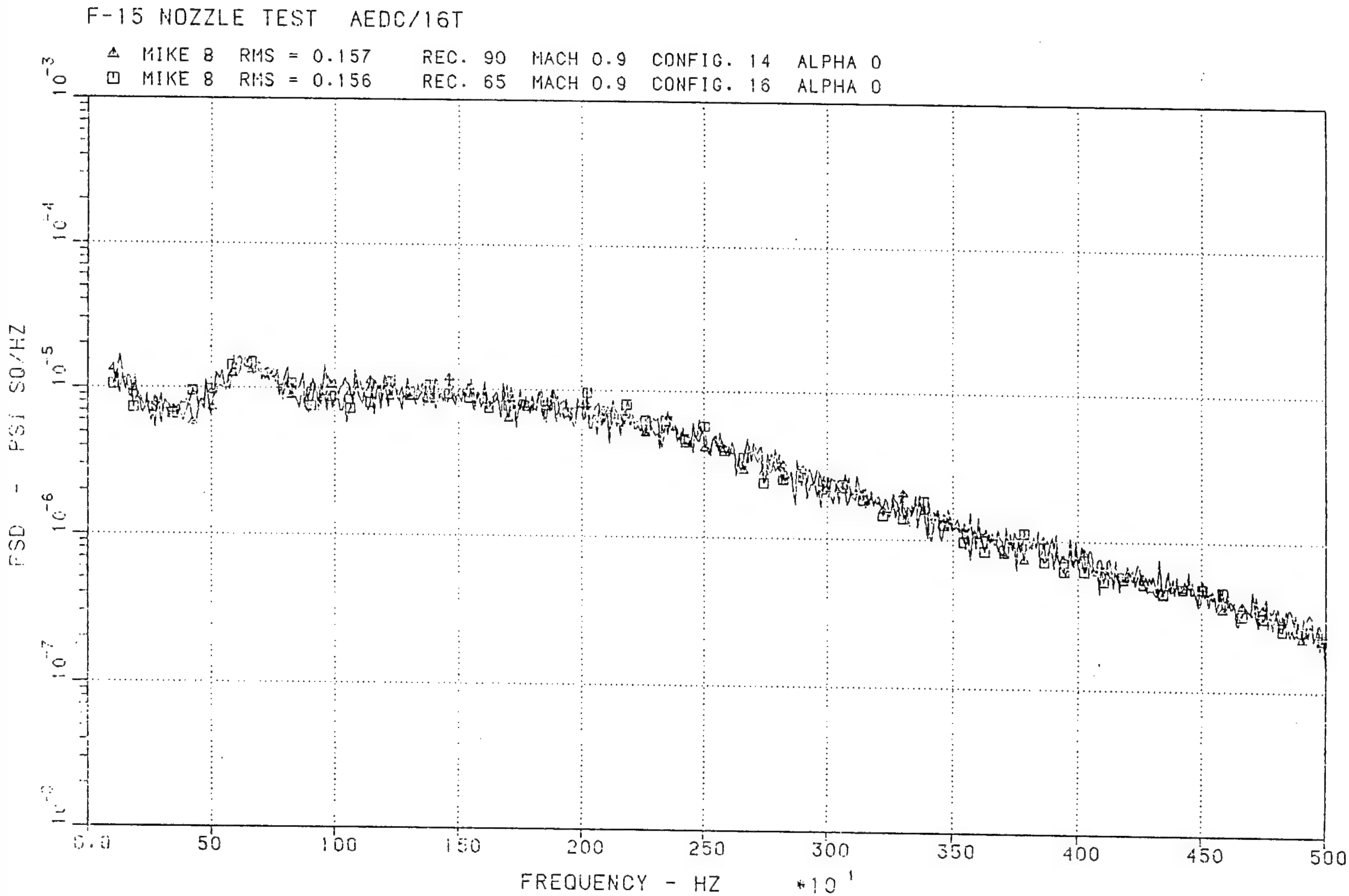

Figure 19 Power Spectral Densities For Configuration 14 and 15

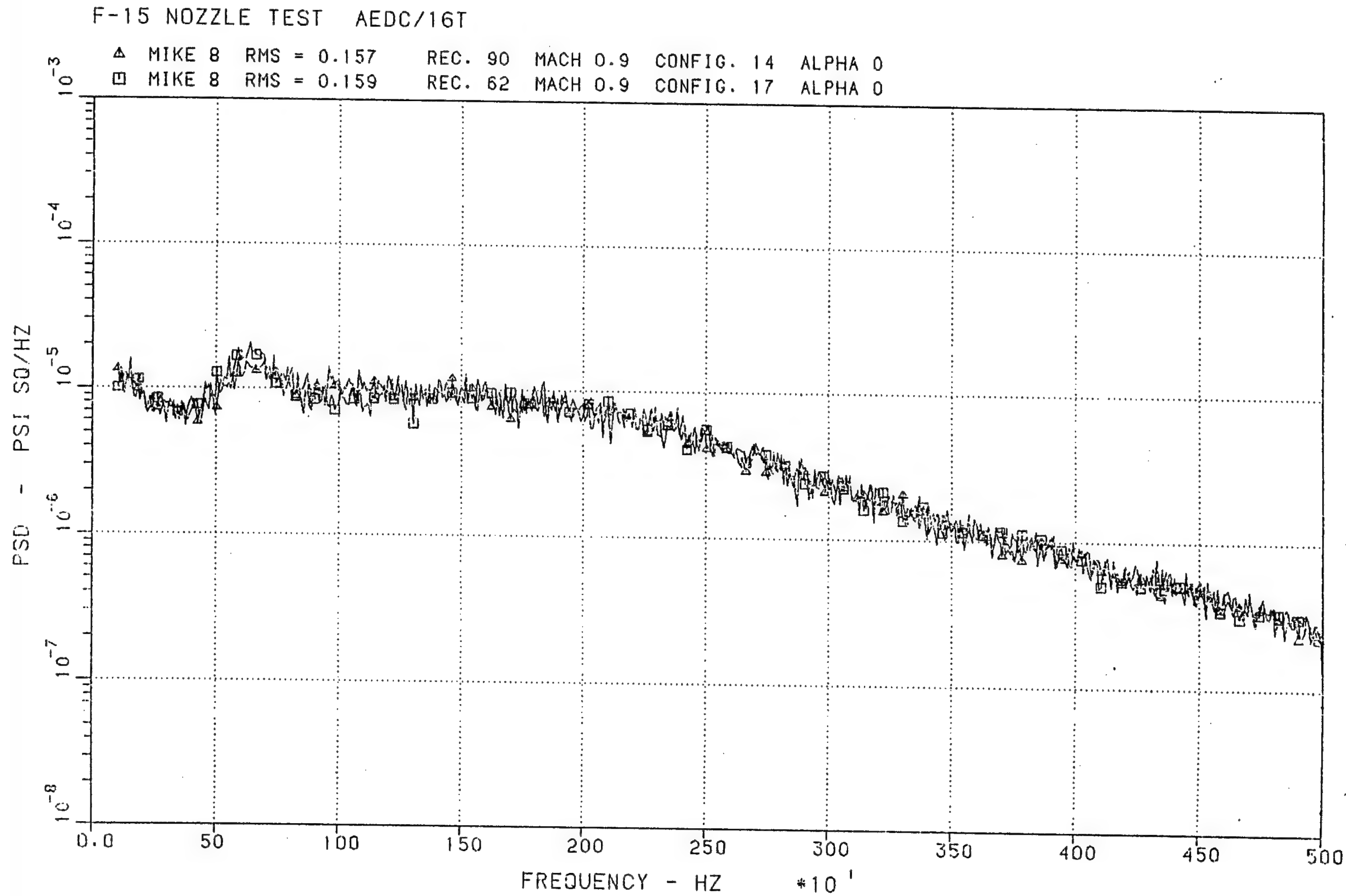

Figure 20 Power Spectral Densities For Configuration 14 and 17

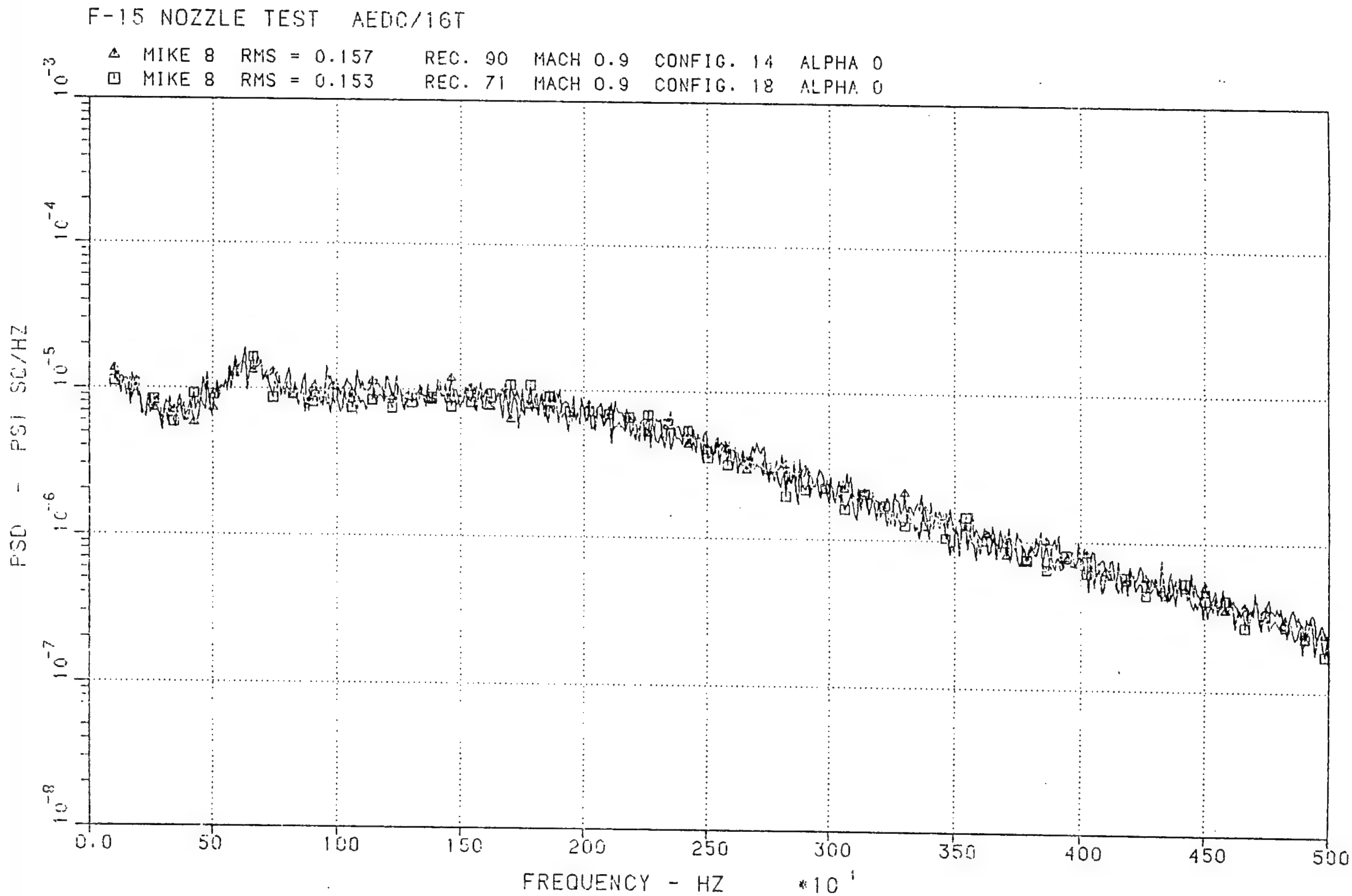

Figure 21 Power Spectral Densities For Configuration 14 and 18

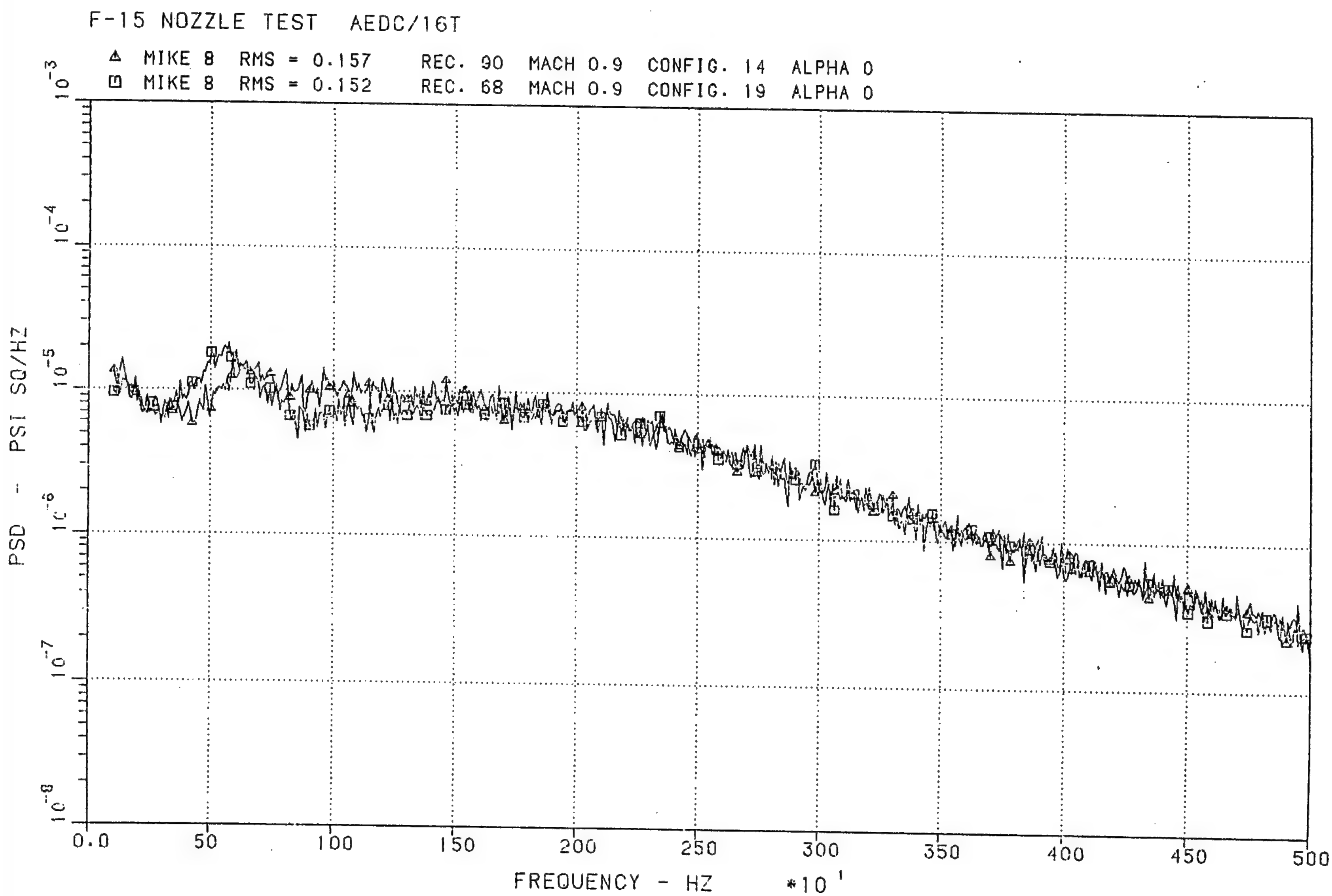

Figure 22 Power Spectral Densities For Configuration 14 and 19

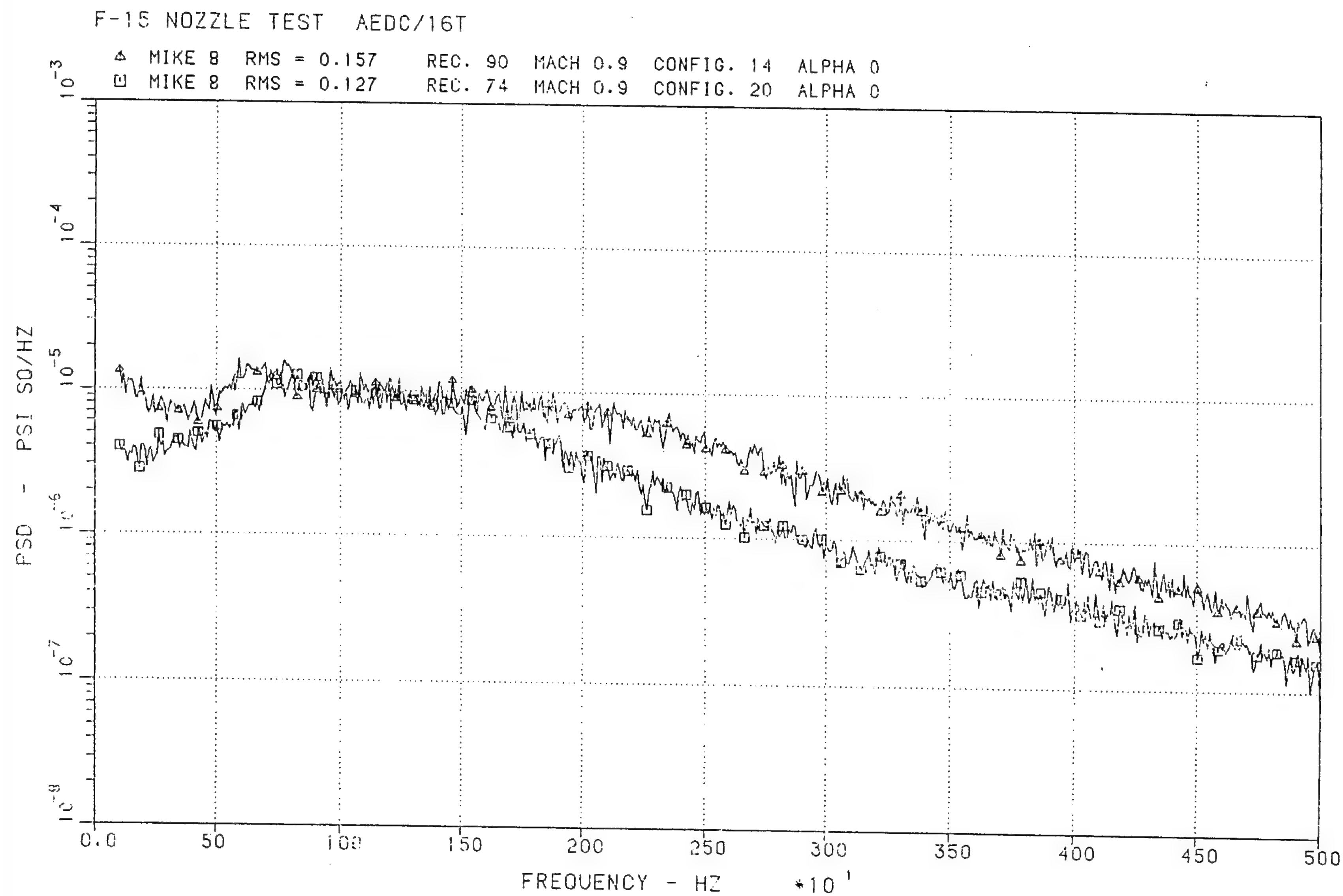

Figure 23 Power Spectral Densities For Configuration 14 and 20

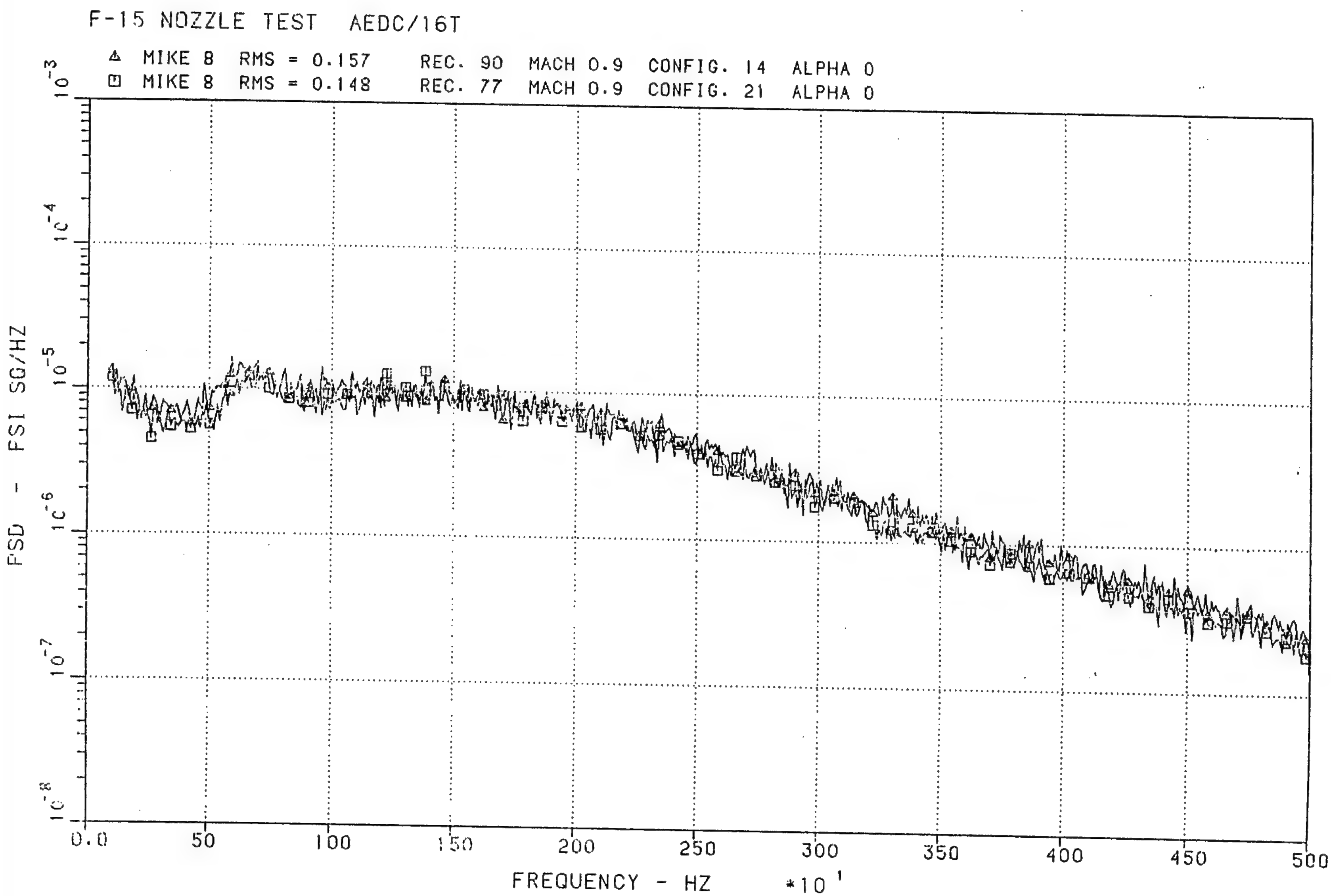

Figure 24 Power Spectral Densities For Configuration 14 and 21

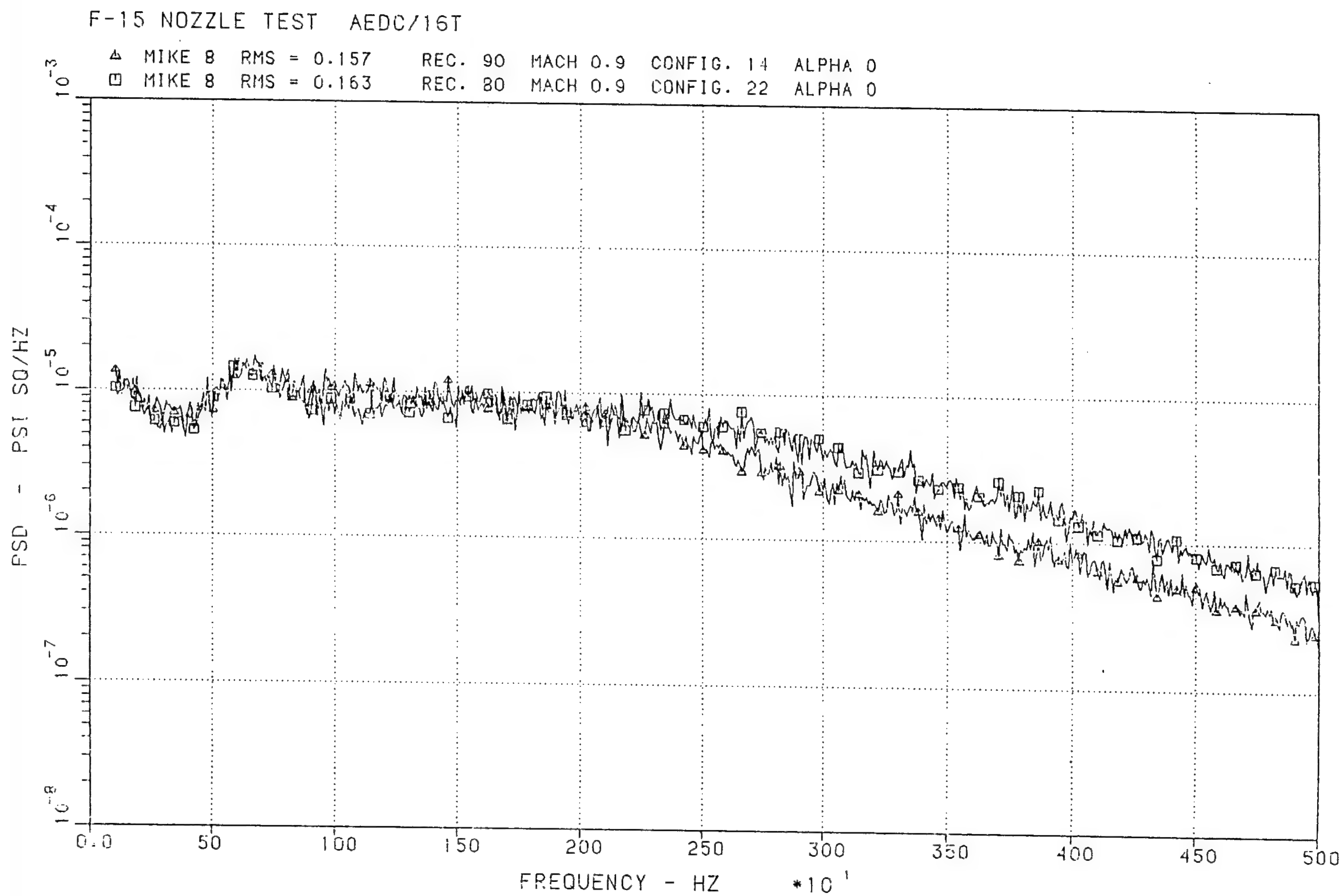

Figure 25 Power Spectral Densities For Configuration 14 and 22

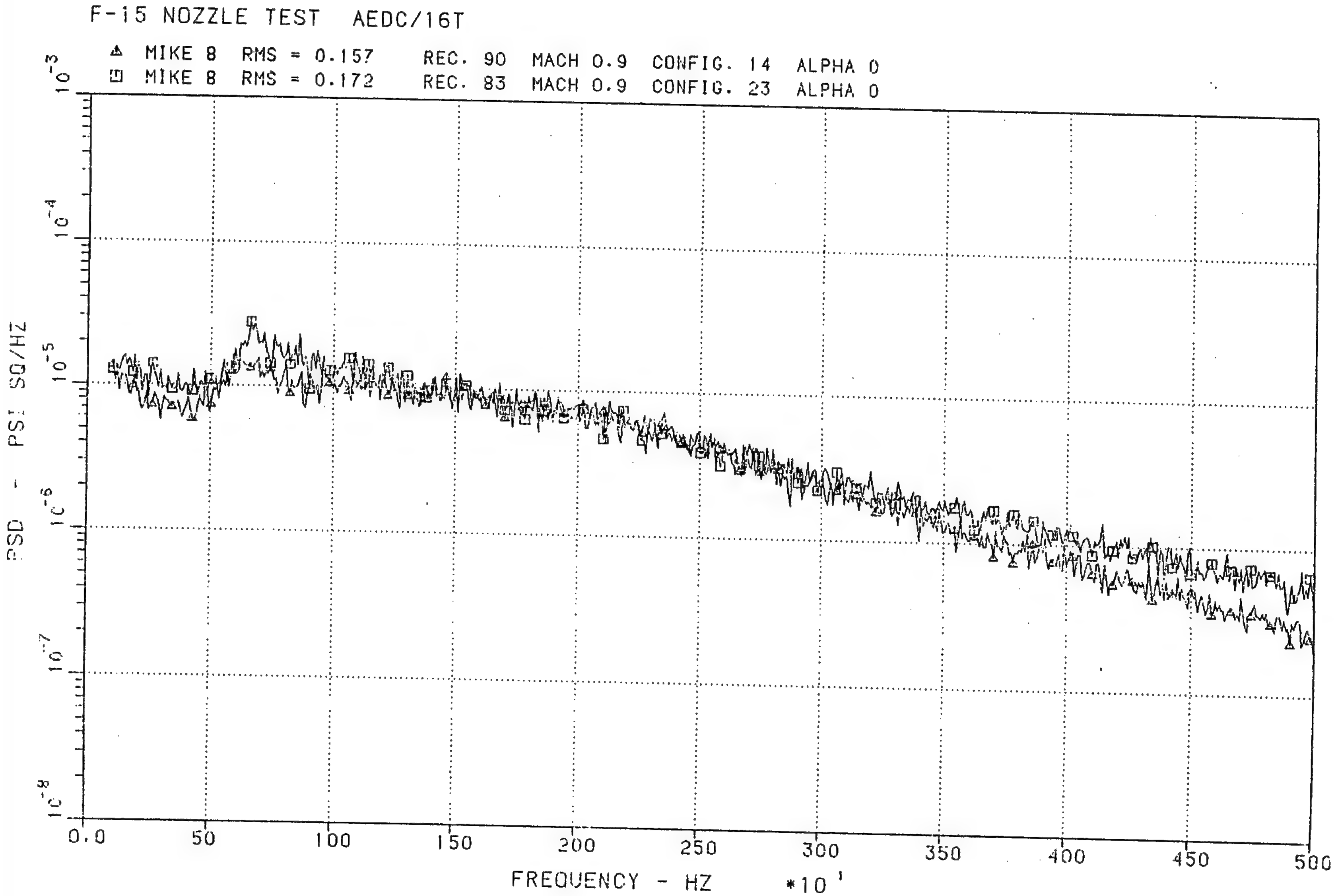

Figure 26 Power Spectral Densities For Configuration 14 and 23

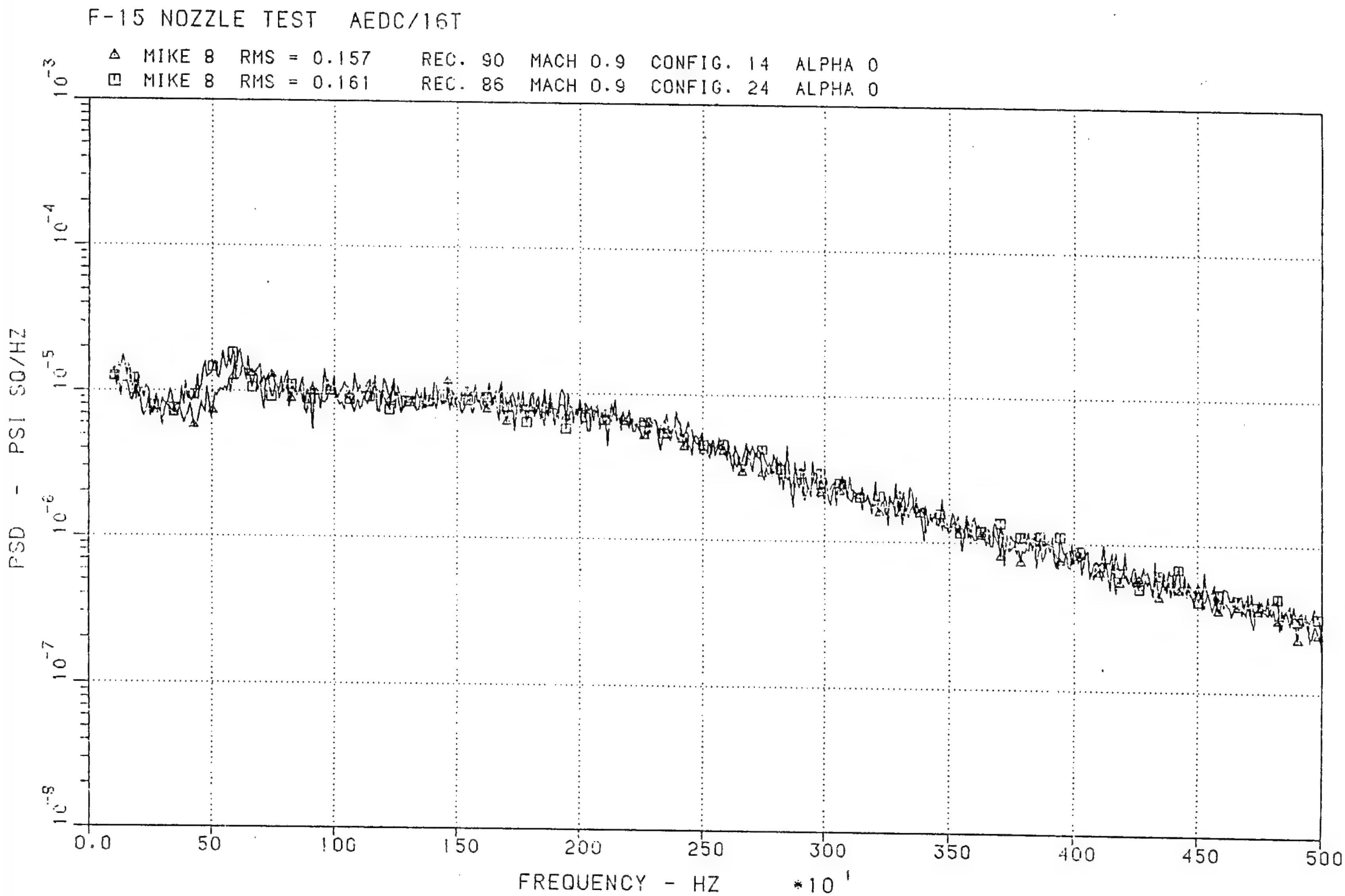

Figure 27 Power Spectral Densities For Configuration 14 and 24

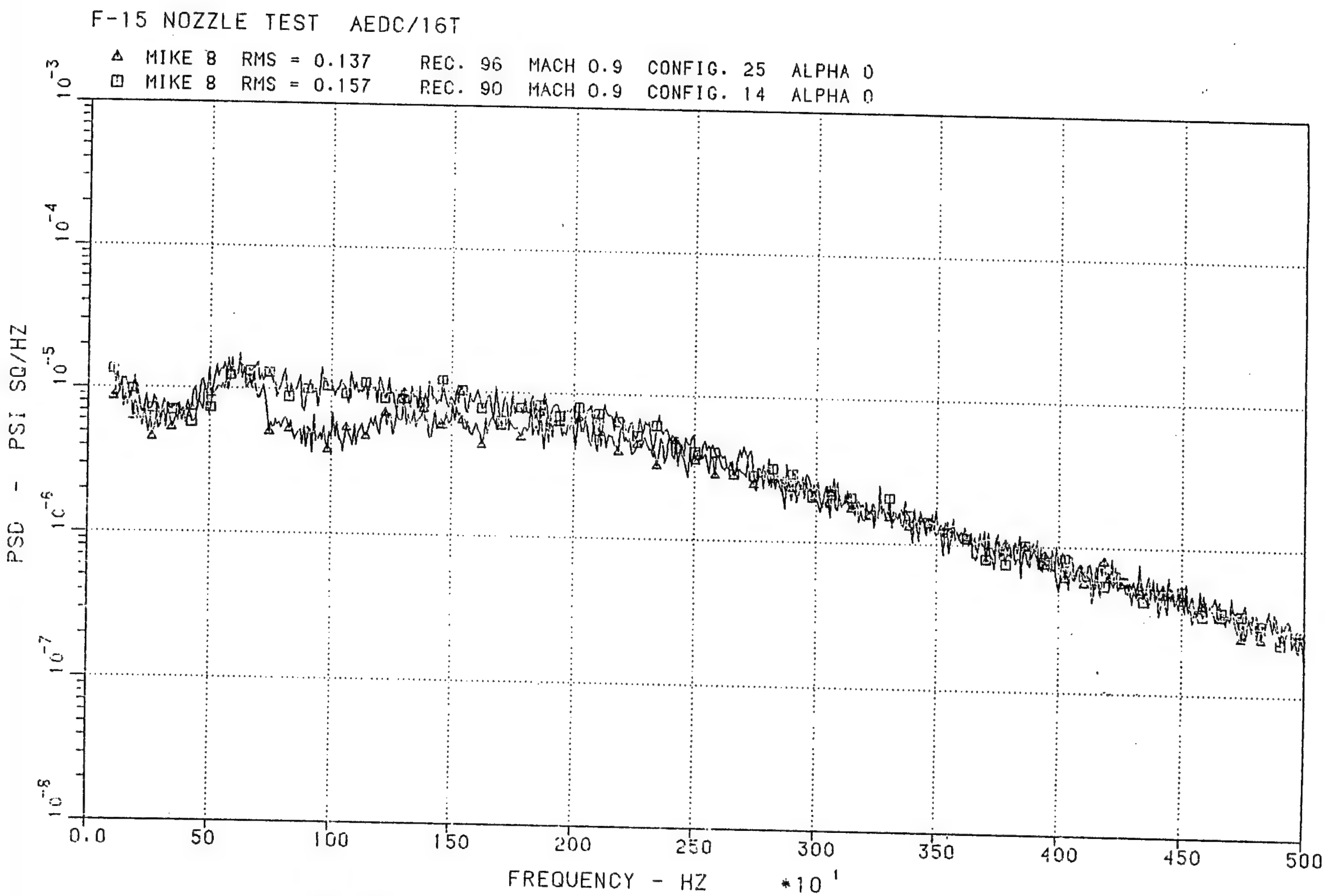

Figure 28 Power Spectral Densities For Configuration 25 and 14

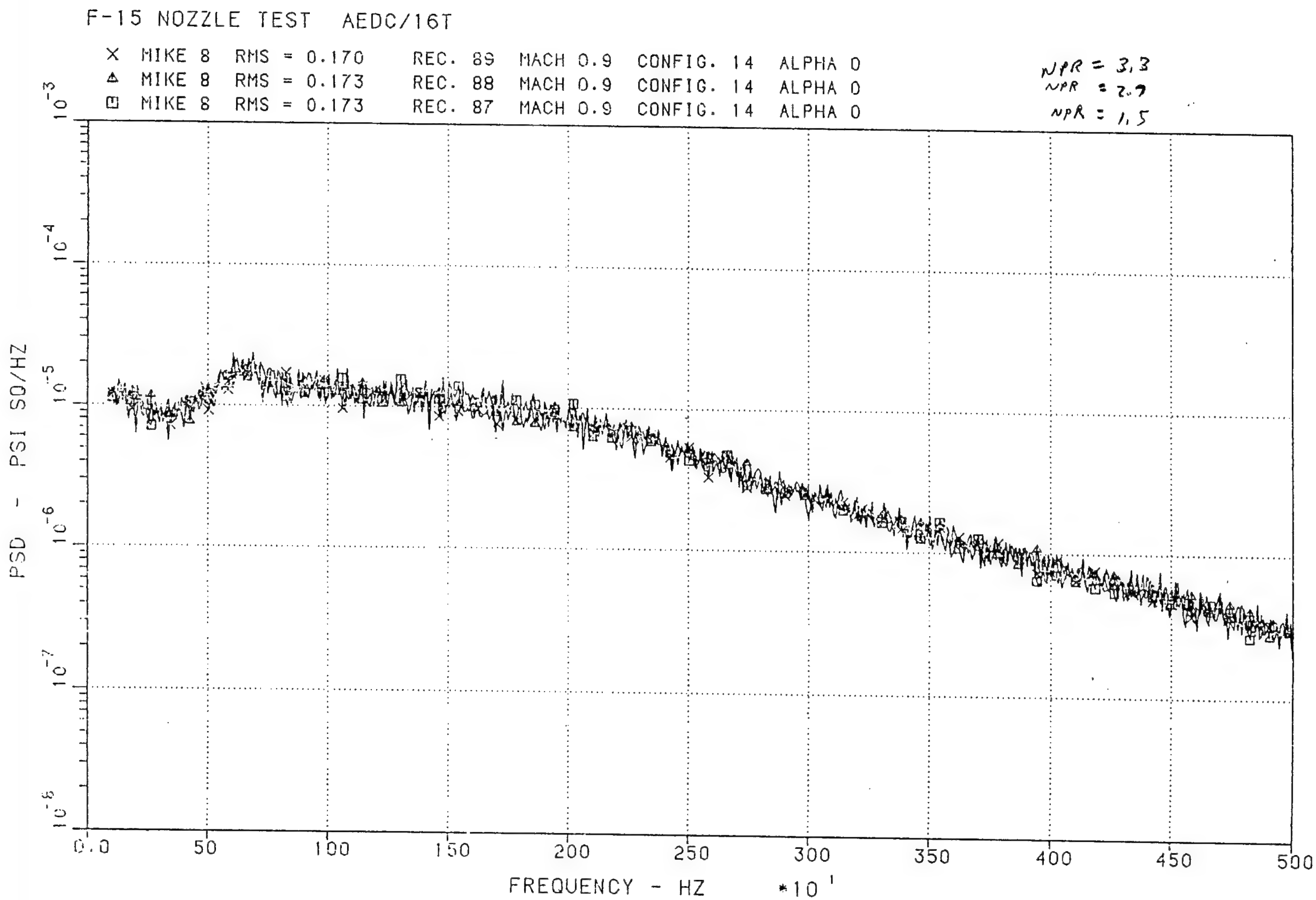

Figure 29 Spectra Showing Effect of NPRs 1.5, 2.7, 3.3.

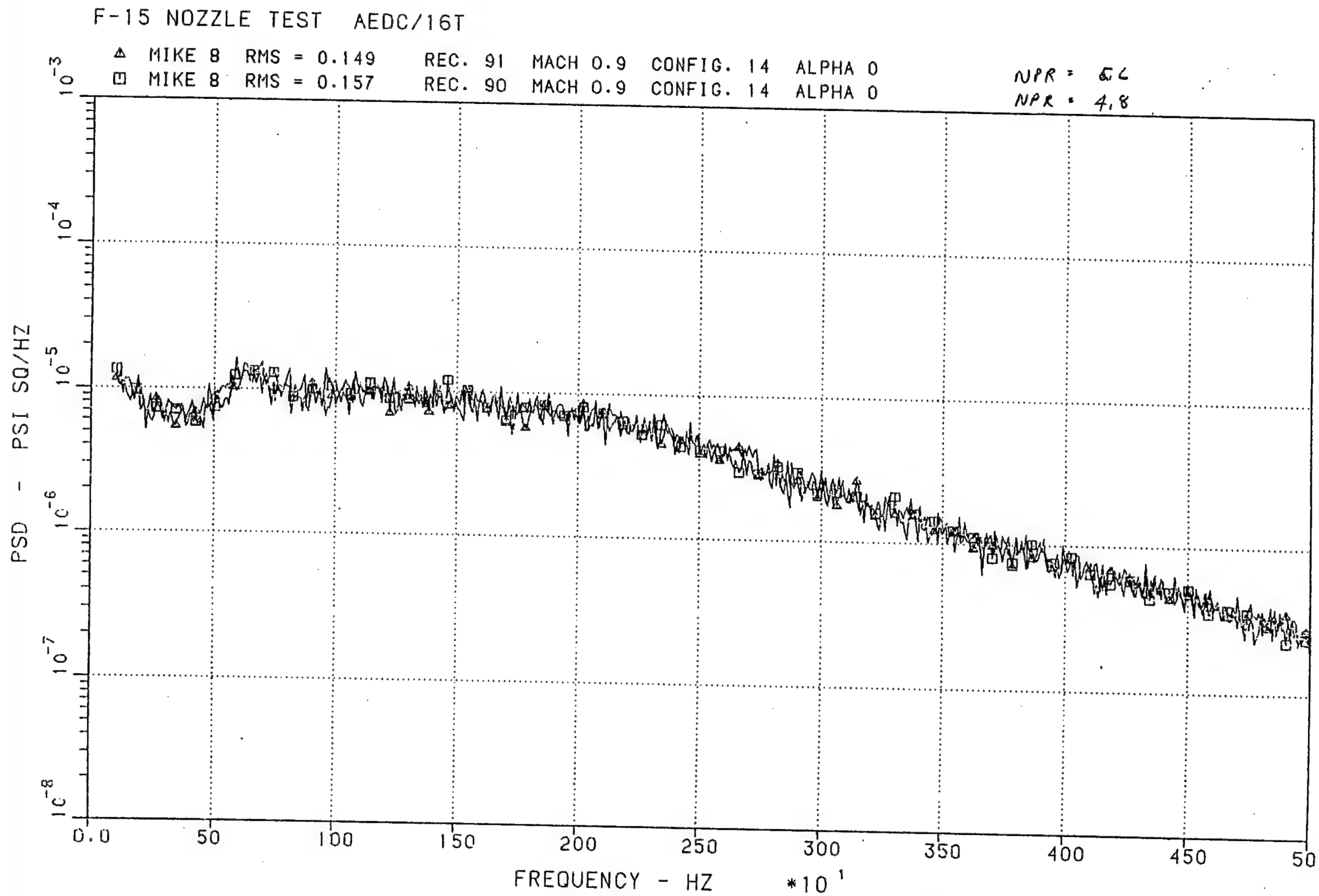

Figure 30 Spectra Showing Effect of NPRs 4.8 and 5.6

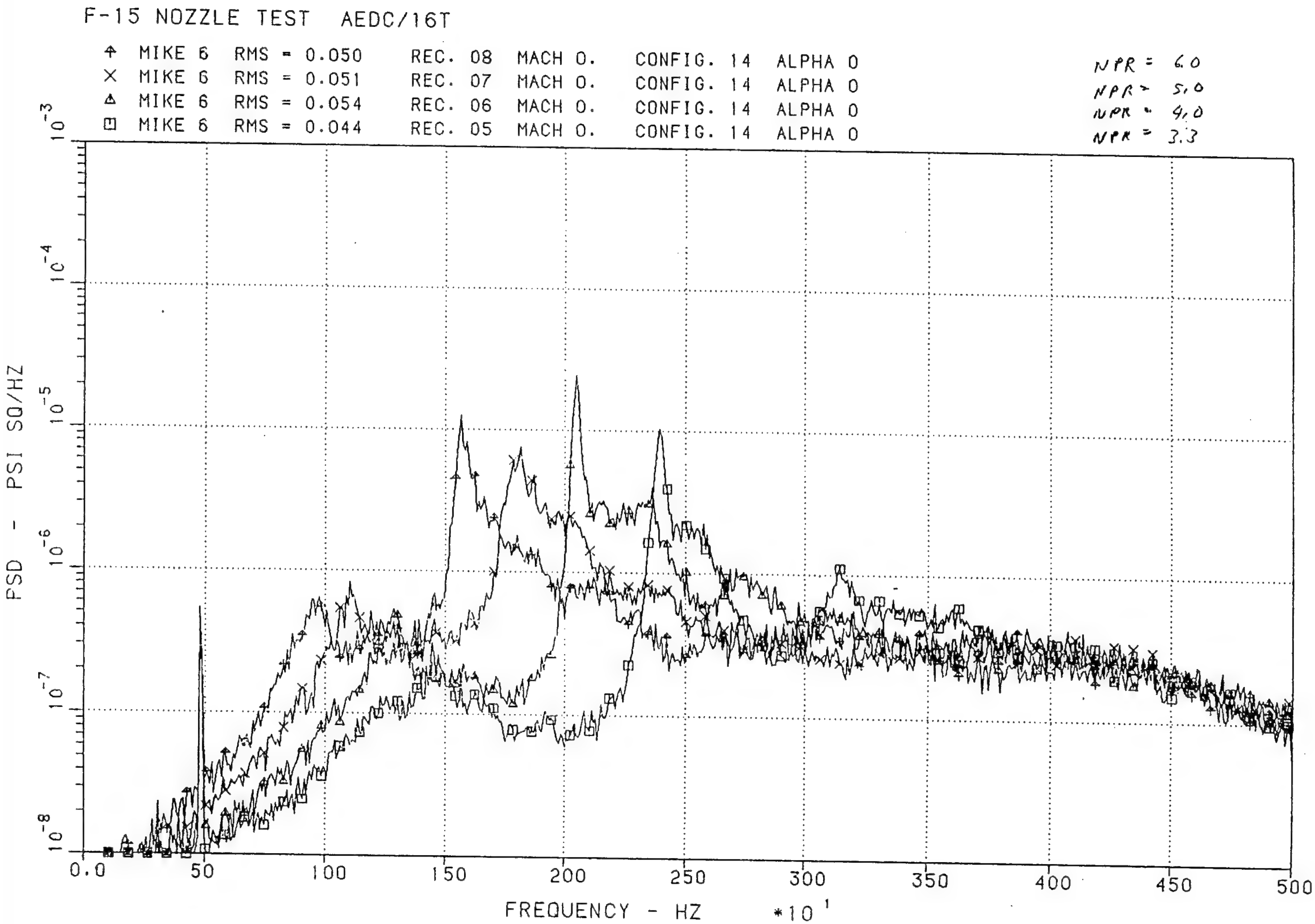

Figure 31 Spectra Showing Effect of NPR For Tunnel Flow of 0.

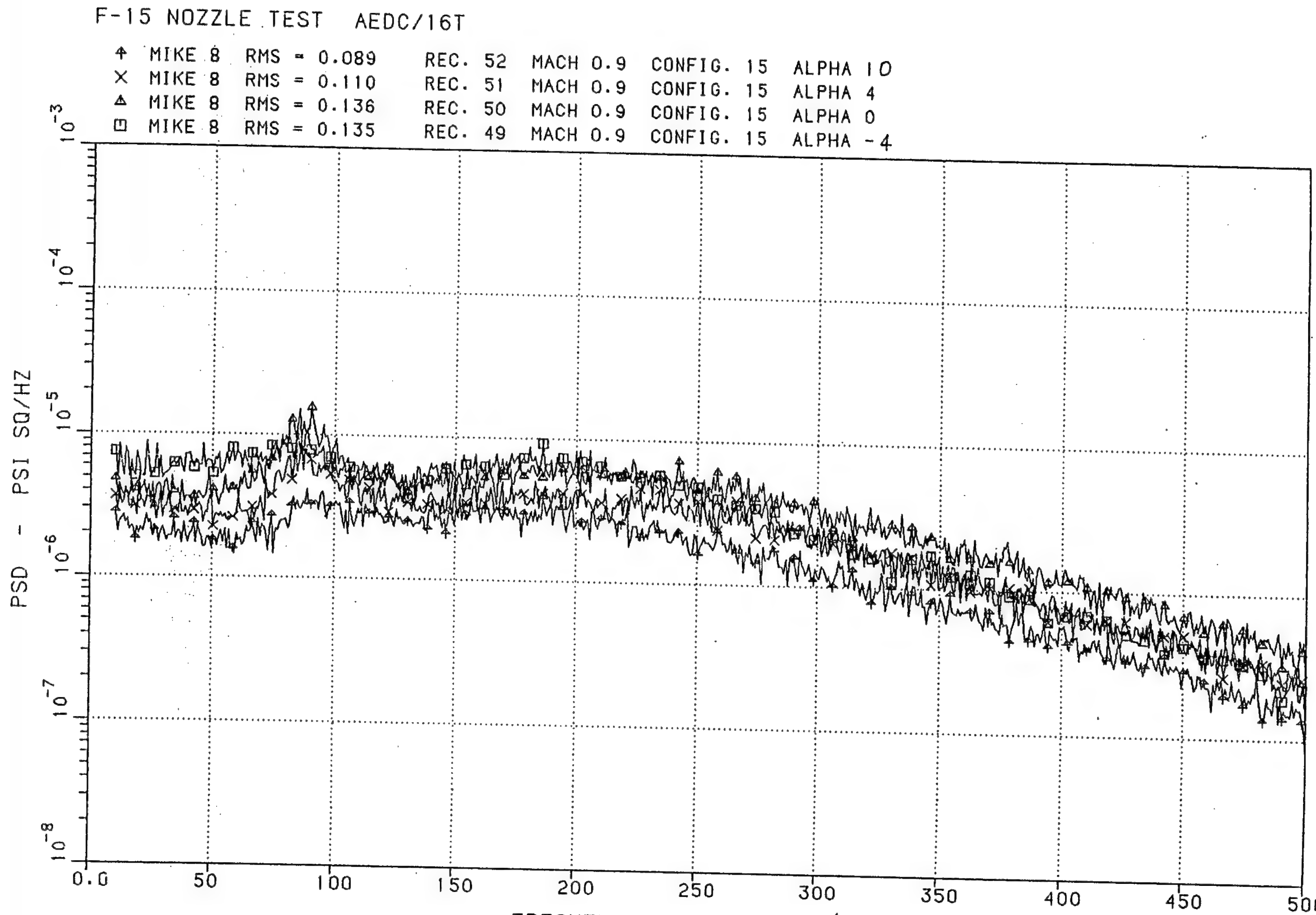

Figure 32 Spectra Showing Effect of Angle-Of- Attack

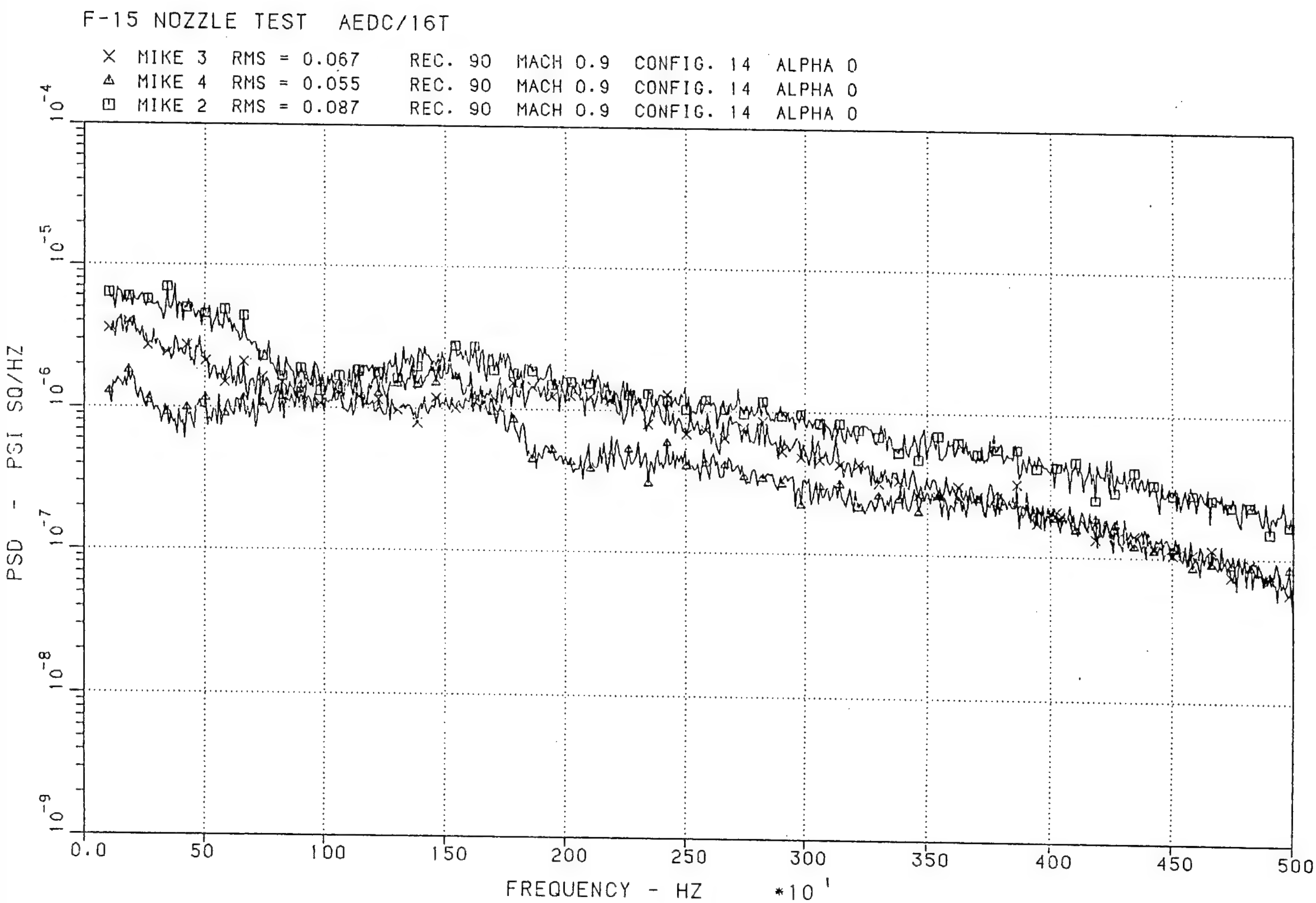

Figure 33 Spectra From Microphone 2, 3, and 4.

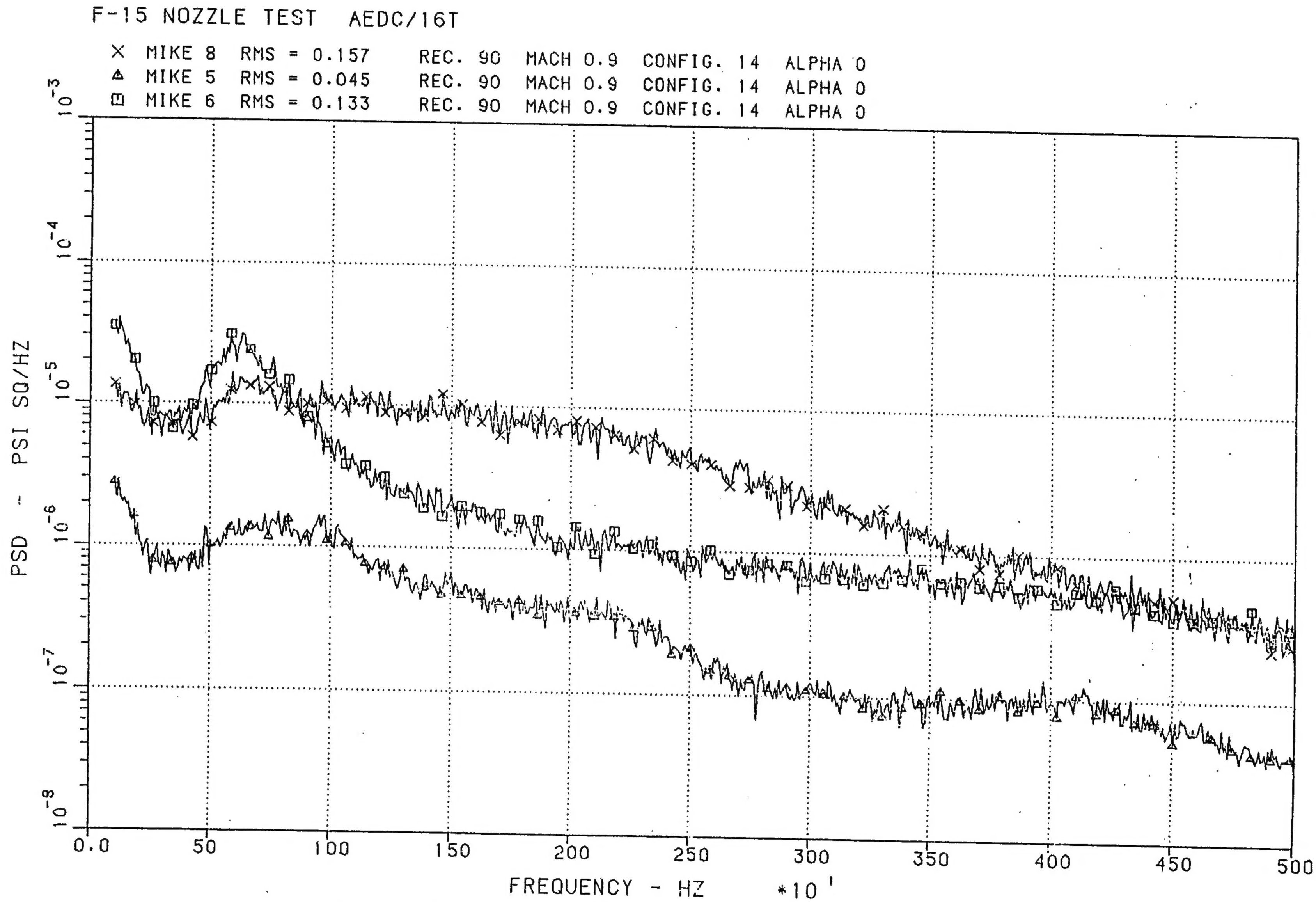

Figure 34 Spectra From Microphone 5, 6, and 8.

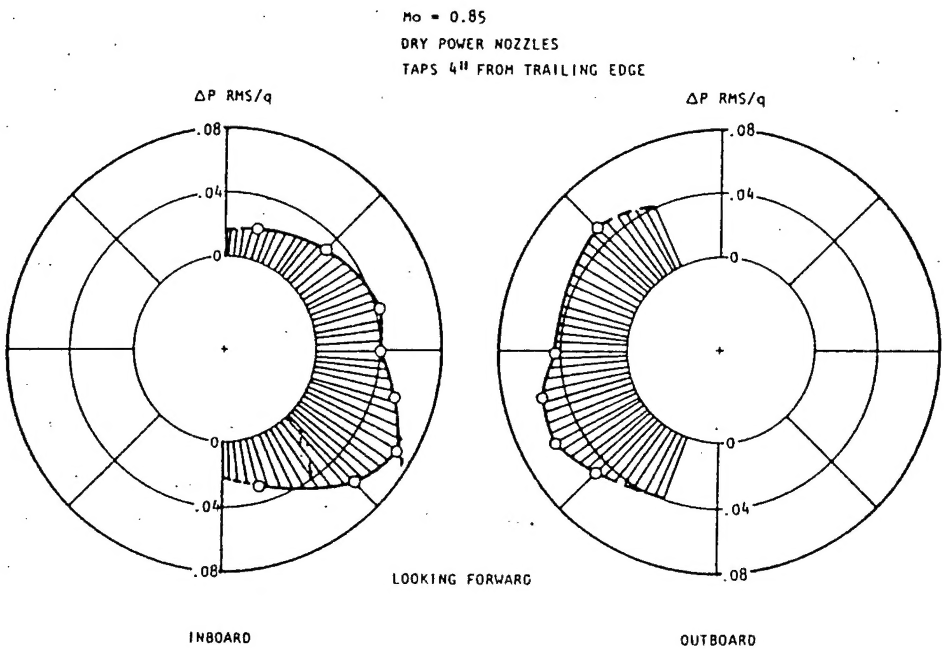

Figure 35 Circimferential Variation of Acoustic Environment On B-1 Model.

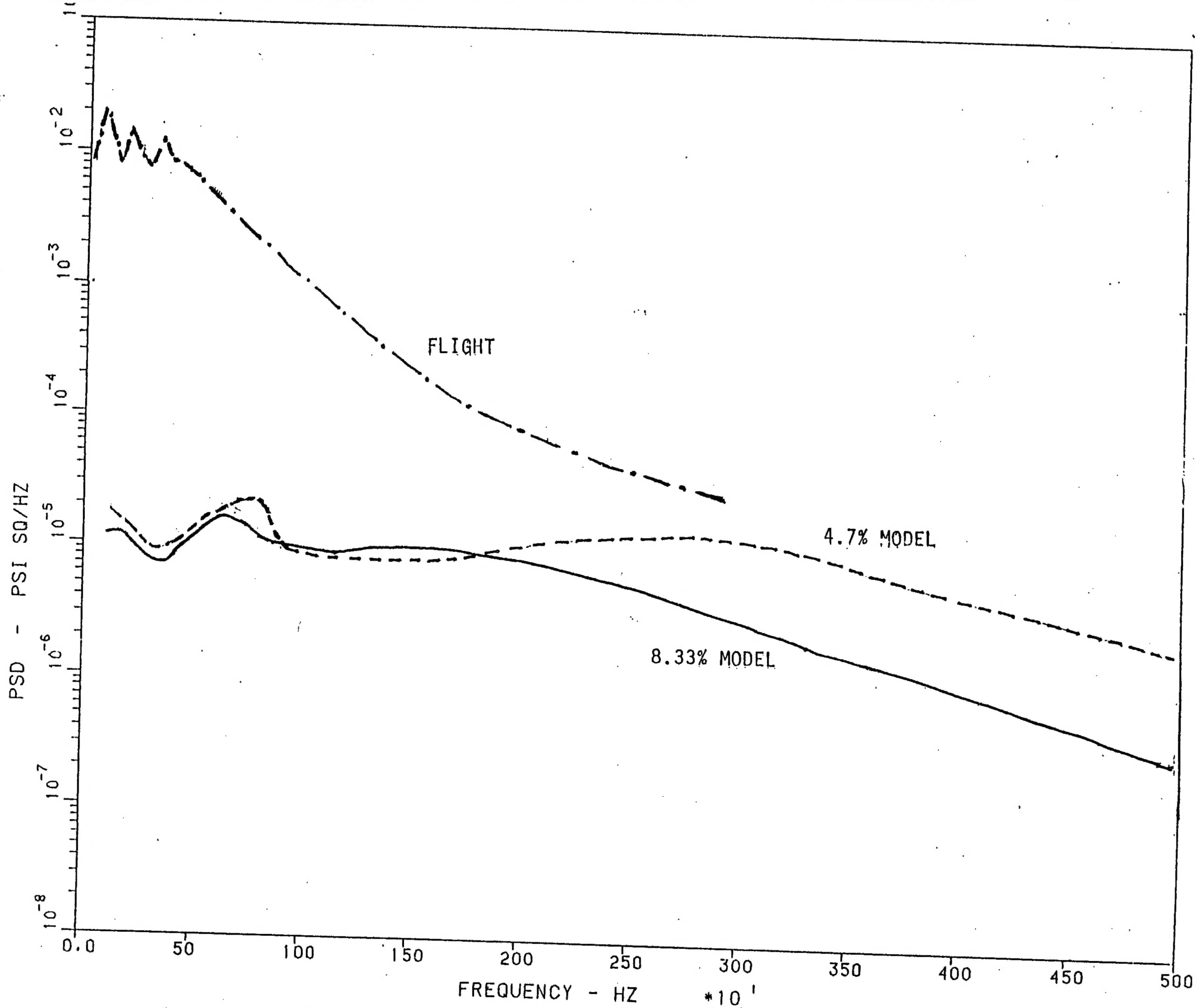

Figure 36 Comparison of 8.33 Percent Data to 4.7 Percent Data and Flight Data

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